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LARVAL CESTODE PARASITES OF EDIBLE MOLLUSKS OF THE NORTHEASTERN GULF OF MEXICO

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ABSTRACT Ten distinct species of larval cestodes were obtained from 43 edible, or potentially edible, benthic mollusks of the northeastern Gulf of Mexico. Three of the infected mollusks, American oysters, *Crassostrea virginica* (Gmelin), Atlantic bay scallops, *Argopecten irradians concentricus* (Say), and sunray venus clams, *Macrocallista nimbosa* (Lightfoot), are important commercial species in the eastern Gulf and the remainder are occasionally eaten by epicurean shellfishermen or were consumed by prehistoric, aboriginal Indians of the Gulf coast. The cestodes represent four orders, seven families and nine recognized genera and include the trypanorhynchs, *Eutetrarhynchus* sp. (of Cake 1975) and *Parachristianella* sp. (of Cake 1975), the lecanicephalideans, *Polypocephalus* sp. (of Cake 1975) and *Tylocephalum* sp. (of Burton 1963), the tetraphyllideans, *Dioecotaenia cancellata* (Linton 1890), *Anthobothrium* sp. (of Cake 1975), *Rhinebothrium* sp. (of Cake 1975), *Acanthobothrium* sp. (of Regan 1963), and *Acanthobothrium* sp. (of Harry 1969), and the diphyllidean, *Echinobothrium* sp. (of Cake 1975). Infected mollusks were widely distributed in coastal estuarine and marine habitats from the Mississippi Sound to the Florida Keys. Pelecypods appear to serve as primary intermediate hosts and molluscivorous gastropods appear to serve as secondary intermediate or paratenic (transport) hosts for these cestodes which in turn utilize demersal elasmobranch fish as final hosts. None of these cestodes are known to infect humans and the only potential harm is to the quality and quantity of the edible molluscan tissues.

INTRODUCTION

This report was derived from a three-year study of larval cestode parasites of shallow-water, benthic mollusks of the eastern Gulf of Mexico. During that study 2,470 mollusks, representing 36 gastropod species, 55 pelecypod species, and one octopod, were collected from 30 localities between Bay St. Louis, Mississippi, and the Dry Tortugas archipelago of Florida and examined for larval cestodes. A list of hosts and parasites and a provisional key to the molluscan cestodes of the eastern Gulf of Mexico has been published elsewhere (Cake 1976). For the sake of brevity, the literature pertaining to molluscan cestodes of the Gulf is presented in synoptic form in Table 1.

The infection data reported and analyzed herein were derived from those mollusks which are harvested by commercial and sport shellfishermen, from those occasionally consumed by epicurean shellfishermen, from those which were consumed by aboriginal Indians of the northern Gulf coast, and from congeners of edible mollusks. These four categories are based on present edibility standards, on the suggestions of the late epicurean, Euell Gibbons (1964), and a senior Gulf coast zoologist, Gordon Gunter (1971), and on archaeological data from Willey (1949) and Percy (1973). Gibbons considered almost any marine or estuarine mollusk edible but his choices in the Gulf were restricted to 10 gastropods and 12 pelecypods. Gunter reported that 15 gastropods and 21 pelecypods from the Gulf were edible or potentially edible. Willey and Percy reported shell remains of 17 gastropods and 14 pelecypods from aboriginal Indian garbage mounds (or kitchen middens) along the northern Gulf coast of Florida.

Only one case of human infection by a related cestode is known. Heinz (1954) reported that a five-year-old Ecuadorian boy spontaneously passed a *Hepatoxylon* sp. larva (Trypanorhyncha) while in a bathtub. The author hypothesized that the larva came from an improperly cooked marine fish of that area which is commonly infected. This should not be considered a true infection since the larva did not establish itself in the boy's body.

The cestode nomenclature follows that of Schmidt (1970) with the exception of *Anthobothrium* Beneden, which he splits, and *Rhinebothrium* Linton, which he does not recognize. The molluscan nomenclature follows that of Abbott (1974).

MATERIALS AND METHODS

Benthic mollusks were collected at 30 Gulf coast localities between Bay St. Louis, Mississippi, and Dry Tortugas, Florida, from shallow, subtidal, grass, mud and sand flats and coral and oyster reef habitats via skin and scuba diving, wading, hand and shovel digging, etc. Based on preliminary studies (Cake 1972), large pelecypods (i.e., clams, oysters, pen shells, scallops) and molluscivorous gastropods (i.e., conchs, tulip snails, whelks) were collected and transported alive in 190-liter styrofoam containers to several coastal marine laboratories for dissection and examination. The following tissues and organs were examined for cestode larvae: in pelecypods—the gills, labial palps, stomach and stomach walls, intestine and intestine walls, intestinal pouches (if present), digestive gland and diverticula, gonads, and foot musculature; in gastropods—the valve of Leiblein (if enlarged), esophagus and esophageal pouches (if present),

TABLE 1.

Synoptic review of larval cestode parasites reported from mollusks of the Gulf of Mexico.

Larval Cestode Species	Molluscan Hosts	Tissue Location	Geographic Locality	Reference	Remarks
TRYPANORHYNCHA					
Parachristianella sp. (as *P. dimegacantha* Kruse)	*Argopecten irradians concentricus* (Say) *Macrocallista nimbosa* (Lightfoot) *Spisula solidissima similis* (Say)	Encysted singly along walls of intestine of all hosts; and in foot musculature of *M. nimbosa* and *S. s. similis*	St. Teresa Beach, Florida	Cake 1972	Encysted
Nybelinia sp. (as "*Scolex*" sp. VIII)	*Donax variabilis* Say *Atrina seminuda* (Lamarck)	Digestive gland	Galveston Beach, Texas	Wardle 1974	
LECANICEPHALIDEA					
Polypocephalus sp.	*A. i. concentricus*	Digestive gland	St. Teresa Beach, Florida	Cake 1972	Encysted singly in small groups in clear-walled sacs
Tylocephalum sp.	*Crassostrea virginica* (Gmelin)	Gills, palps, gut epithelium	Apalachicola Bay, Florida	Burton 1963	Encysted
Tylocephalum sp.	*C. virginica*	Connective and Leydig tissues	Choctawhatchee and Tampa Bays, Florida	Quick 1971	Encysted
Tylocephalum sp. (of Burton 1963)	*A. i. concentricus* *M. nimbosa* *S. s. similis*	Digestive tract walls, and digestive gland of all hosts; foot of *M. nimbosa* and *S. s. similis*	St. Teresa Beach, Florida	Cake 1972	Encysted
TETRAPHYLLIDEA					
Acanthobothrium sp. (as "*Scolex pleuronectis*" Müeller)	*Melongena corona* Gmelin	Mantle cavity	Live Oak Island, Apalachee Bay, Florida	Regan 1963	Free in cavity
Acanthobothrium sp. (of Regan 1963)	*Fasciolaria tulipa* Linné	Digestive tract	Mullet Key, Tampa Bay, Florida	Friedl and Simon 1970	Free in gut
Acanthobothrium sp. (of Regan 1963)	*F. tulipa* *Fasciolaria lilium hunteria* (Perry) *Pleuroploca gigantea* (Kiener) *M. corona* *Polinices duplicatus* (Say)	Digestive tract	Alligator Harbor (Region), Franklin County, Florida	Hamilton and Byram 1974	Free in gut
Acanthobothrium sp. (of Regan 1963)	*P. gigantea* *Thais haemastoma* (Linné)	Digestive tract	Galveston Beach, Texas and off-shore platforms in area	Wardle 1974	Free in gut
Acanthobothrium sp. (as "*Scolex pleuronectis*" Müeller)	*Raeta* (= *Anatina*) *plicatella* Lamarck	Gutwall cysts or sacs	Galveston Bay, Texas	Harry 1969	Plerocercoids share cysts or sacs
Acanthobothrium sp. (of Harry 1969)	*Tagelus plebeius* (Solander) *Macoma constricta* (Bruguière)	Stomach and intestines	Galveston Bay, Texas	Wardle 1974	Free in gut
Dioecotaenia cancellata (Linton)	*Anadara ovalis* (Bruguière)	Stomach and intestines	Galveston Beach, Texas	Wardle 1974	Free in gut
Anthobothrium sp. (as *Rhodobothrium* sp.)	*M. nimbosa*	Visceral mass/mantle cavity	St. Teresa Beach, Florida	Cake 1972	Claviform sac containing worm hangs in mantle cavity
Anthobothrium sp. (of Cake 1972)	*D. variabilis*	Visceral mass/mantle cavity	Galveston Beach, Texas	Wardle 1974	Claviform sac containing worm hangs in mantle cavity

TABLE 1 (Continued).

Synoptic review of larval cestode parasites reported from mollusks of the Gulf of Mexico.

Larval Cestode Species	Molluscan Hosts	Tissue Location	Geographic Locality	Reference	Remarks
TETRAPHYLLIDEA (Continued)					
Rhinebothrium sp. (as *Echeneibothrium* sp.)	*A. i. concentricus* *M. nimbosa* *S. s. similis*	Stomach and digestive diverticula	St. Teresa Beach, Florida	Cake 1972	Free in gut, confined in diverticula
Rhinebothrium sp. (of Cake 1972)	*A. seminuda* *Crepidula fornicata* (Linnē) *C. plana* Say *Dosinia discus* Reeve *Noetia ponderosa* (Say) *Periploma inequale* (C. B. Adams) *R. plicatella*	Stomach and intestine	Galveston Beach, Texas	Wardle 1974	Free in gut, confined in diverticula

stomach and stomach walls, digestive gland and diverticula.

All examinations were made with the aid of a stereoscopic, dissecting microscope. The larvae were removed or excised (if encysted), identified (usually to family or species type), counted and either fixed and preserved or placed in petri dishes of filtered seawater (at 30‰ salinity and ambient temperature) for further observations. Selected larvae of *Acanthobothrium* spp., *Rhinebothrium* sp., and *Polypocephalus* sp. were incubated for up to 150 hours in a glucose-enriched, artificial elasmobranch saline medium (*vide:* Read et al. 1960; Hamilton and Byram 1974) to facilitate identification. During incubation some larval features (e.g., apical suckers and bothridial precursors) were lost or modified (e.g., quadriloculate bothridia became triloculate with terminal suckers or pads on *Acanthobothrium* spp. larvae), and some rudimentary adult features developed (e.g., bothridial hooks on larvae of *Acanthobothrium* spp.).

The larvae were killed in an expanded or relaxed condition with tepid tap water or hot (ca 50°C) alcohol-formalin-acetic acid (AFA), fixed in AFA, and preserved in 70% ethanol with 5% glycerine. Large post-plerocercoids of *Anthobothrium* sp. were killed in an expanded condition (bothridia attached to petri dish bottom) with liquid nitrogen and fixed and preserved as above. The larvae were stained with either Van Cleave's combination hematoxylin or Erlich's acid hematoxylin and mounted on slides via standard helminthological techniques.

RESULTS

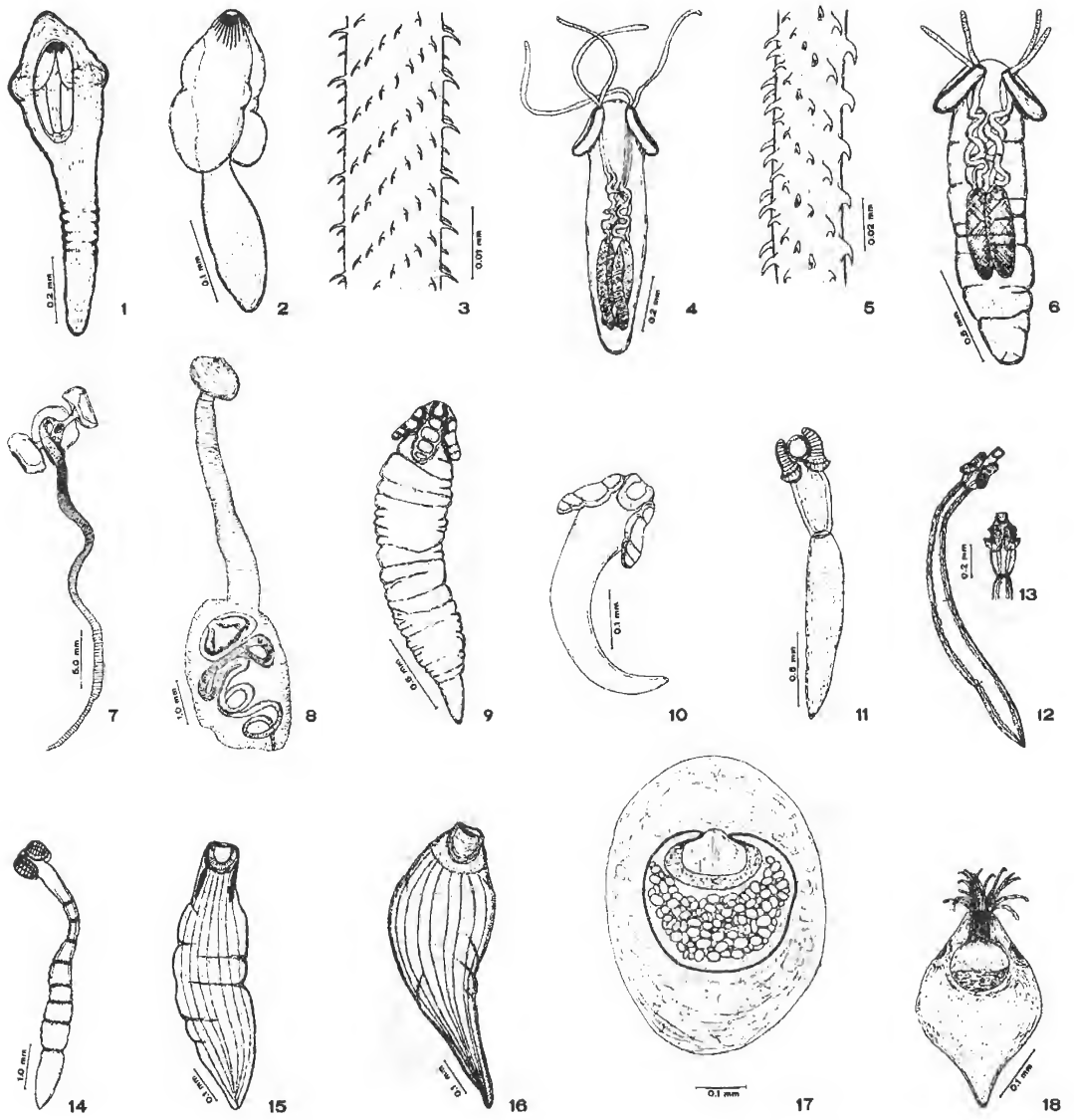
Ten distinct species of larval cestodes were recovered from 43 edible or potentially edible, benthic mollusks of the eastern Gulf of Mexico. The cestodes represent four orders, seven families and nine recognized genera as follows:

Order: Trypanorhyncha
Family: Eutetrarhynchidae
Genus: *Eutetrarhynchus* sp. (of Cake 1975)
Parachristianella sp. (of Cake 1975)
Order: Lecanicephalidea
Family: Lecanicephalidae
Genus: *Polypocephalus* sp. (of Cake 1975)
Family: Cephalobothriidae
Genus: *Tylocephalum* sp. (of Burton 1963)
Order: Tetraphyllidea
Family: Dioecotaeniidae
Genus: *Dioecotaenia cancellata* (Linton 1890)
Family: Phyllobothriidae
Genus: *Anthobothrium* sp. (of Cake 1975)
Rhinebothrium sp. (of Cake 1975)
Family: Onchobothriidae
Genus: *Acanthobothrium* sp. (of Regan 1963)
Acanthobothrium sp. (of Harry 1969)
Order: Diphyllidea
Family: Echinobothriidae
Genus: *Echinobothrium* sp. (of Cake 1975)

Those ten species and two unidentified tetraphyllidean larval forms are illustrated in Figures 1–18. The unidentified forms (Figures 15 and 16) are probably early plerocercoids of *Acanthobothrium* sp. (of Regan 1963) (Figure 9) and *Rhinebothrium* sp. (of Cake 1975) (Figures 11, 12, and 13), respectively. The early plerocercoids of each species concurrently infect the same molluscan host as the advanced, identifiable plerocercoids and in some instances a complete developmental sequence of plerocercoids is present in a single host.

A complete list of molluscan hosts for these cestodes was published previously (Cake 1976, Table 1). The edible molluscan hosts of each cestode are listed along with appropriate bibliographic data on their actual or potential edibility in Table 2.

Seven species of edible pelecypods (by present standards) were infected by one or more larval cestode species. Three of those pelecypods–bay scallops, *Argopecten irradians*



Figures 1–18. Larval cestodes of Gulf of Mexico mollusca (after Cake 1976). 1. Longicaudate, invaginated acanthorostellobothridiocysticercoid of *Echinobothrium* sp. (of Cake) from *Nassarius vibex*. (Cut-away view showing invaginated scolex.) 2. Scolex of *Echinobothrium* sp. (of Cake) from *N. vibex*. 3. Metabasal armature of internal tentacle surface of *Eutetrarhynchus* sp. (of Cake) tentaculoneoplerocercoid from *Pleuroploca gigantea*. 4. Tentaculo-neoplerocercoid of *Eutetrarhynchus* sp. (of Cake) from *P. gigantea*. 5. Side view of metabasal armature of tentacle of *Parachristianella* sp. (of Cake) tentaculo-neoplerocercoid from *Macrocallista nimbosa*. 6. Tentaculoneoplerocercoid of *Parachristianella* sp. (of Cake) from *M. nimbosa*. 7. Bothridio-postplerocercoid of *Anthobothrium* sp. (of Cake) from *Anadara transversa*. 8. Claviform capsule containing bothridio-postplerocercoid of *Anthobothrium* sp. (of Cake) from *A. transversa*. (Cut-away view showing coiled postplerocercoid.) 9. Bothridio-plerocercoid of *Acanthobothrium* sp. (of Regan) from *Oliva sayana*. 10. Bothridio-plerocercoid of *Acanthobothrium* sp. (of Harry) from *Ensis minor*. 11. Bothridio-plerocercoid of *Rhinebothrium* sp. (of Cake) from *Argopecten irradians concentricus*. 12. Bothridio-plerocercoid of *Rhinebothrium* sp. (of Cake) from *Busycon spiratum pyruloides*. 13. Contracted scolex (bothridia) of *Rhinebothrium* sp. from *B. s. pyruloides*. 14. Bothridio-plerocercoid of *Dioecotaenia cancellata* (Linton 1890) from *Chione cancellata*. 15. Uniacetabulo-plerocercoid of *Acanthobothrium* sp. (of Regan) from *Fasciolaria tulipa*. 16. Uniacetabulo-plerocercoid of *Rhinebothrium* sp. (of Cake) from *C. cancellata*. 17. Encysted, acaudate glando-procercoid of *Tylocephalum* sp. (of Burton) from *Argopecten irradians concentricus*. 18. Tentaculo-plerocercoid of *Polypocephalus* sp. (of Cake) from *A. i. concentricus*.

TABLE 2.

Summary of larval cestode parasites of edible or potentially edible benthic mollusks of the eastern Gulf of Mexico.

Edible Mollusks Found to be Infected During the Present Study	Larval Cestode Species											References to Edible Mollusks
	Acanthobothrium (Regan)	*Acanthobothrium* (Harry)	*Anthobothrium* sp.	*Dioecotaenia cancellata*	*Rhinebothrium* sp.	Unknown Tetraphyllidean*	*Echinobothrium* sp.	*Eutetrarhynchus* sp.	*Parachristianella* sp.	*Polypocephalus* sp.	*Tylocephalum* sp. (Burton)	1. Gibbons 1964 2. Gunter 1971 3. Percy 1973 4. Willey 1949 5. Present Study
GASTROPODS:												
Busycon contrarium (Conrad) (as *B. preversum*-2)					X						X	1, 2, 3, 4
Busycon spiratum pyruloides (Say)	X				X	X		X	X		X	1, 2, 3
Cantharus cancellarius (Conrad)	X				X	X	X		X		X	2
Crepidula spp.					X	X		X	X		X	1, 2, 4
Fasciolaria lilium hunteria (Perry) (as *F. distans*-3)	X				X	X		X	X		X	2, 3
Fasciolaria tulipa (Linné) (as *Fasciolaria* sp.-3)	X				X	X		X	X		X	3, 4
Melongena corona Gmelin	X			X	X	X		X			X	2, 3, 4
Murex fulvescens Sowerby											X	2, 3, 4
Murex sp. [probably *M. pomum* (Gmelin)]	X										X	3
Oliva sayana Ravenel	X				X						X	2, 3, 4
Pleuroploca gigantea (Kiener) (as *Fasciolaria g.*-3)	X				X			X			X	2, 3
Polinices duplicatus (Say)	X	X			X				X		X	1, 2, 3, 4
Thais haemastoma canaliculata (Gray) (as *Thais* sp.-1)								X			X	1, 2
PELECYPODS:												
Arca sp.											X	3
Argopecten irradians concentricus (Say) (as *Pecten* sp.-3, 4)		X	X		X	X		X	X	X	X	2, 3, 4
Atrina rigida (Lightfoot)					X			X	X		X	1
Atrina seminuda (Lamarck)								X	X		X	2
Chama macrophylla (Gmelin)											X	3
Chione (spp.-1) *cancellata* (Linné)				X	X	X			X		X	1, 2, 3, 4
Crassostrea virginica (Gmelin) (as *Ostrea v.*-3, 4)											X	1, 2, 3, 4
Crytopleura costata (Linné)						X					X	1
Dinocardium robustum (Lightfoot) (as *Cardium* sp.-3)											X	1, 2, 3
Donax variabilis (Say)					X				X		X	1, 2, 3
Dosinia discus (Reeve)					X	X			X		X	2, 3
Dosinia elegans Conrad					X						X	5
Ensis spp.		X			X	X		X			X	1
Laevicardium sp.											X	1
Macrocallista maculata (Linné)									X		X	5
Macrocallista nimbosa (Lightfoot)			X						X		X	2
Mercenaria campechiensis (Gmelin) (as *Venus* sp.-3)											X	1, 2, 3
Mercenaria m. texana (Dall) (as *Venus m.*-3, 4)											X	1, 2, 3, 4
Modiolus m. squamosus Beauperthuy						X					X	5
Noetia ponderosa (Say)	X				X	X			X		X	2, 3
Periglypta listeri (Gray)											X	5
Pinctada imbricata Röding											X	5
Pinna carnea Gmelin											X	1
Pseudochama radians (Lamarck)											X	5
Pseudomiltha floridana (Conrad) (as *Lucina f.*)		X										2
Pteria colymbus (Röding)											X	5
Spisula solidissima similis (Say)			X		X				X		X	1, 2, 3
Spondylus americanus Hermann											X	5
Tagelus plebeius (Solander)		X			X							2
Tagelus spp.		X			X							1
Trachycardium egmontianum (Shuttleworth)					X						X	1

*Uniacetabulo-plerocercoids of *Acanthobothrium* sp. (Regan) and/or *Rhinebothrium* sp. (Cake)

concentricus (Say); American oysters, *Crassostrea virginica* (Gmelin); and sunray venus clams, *Macrocallista nimbosa* (Lightfoot)—are harvested commercially in the northeastern Gulf. Four additional species—the southern and Texas quahog clams, *Mercenaria campechiensis* (Gmelin) and *M. mercenaria texana* (Dall); the surf clam, *Spisula solidissima similis* (Say); and the coquina or beach clam, *Donax variabilis* (Say)—are frequently collected and consumed by sport shellfishermen, skin and scuba divers and beachcombers. Large quantities of oysters are consumed raw (alive on the half shell), while the remaining species are baked, broiled, chowdered, fried, steamed, etc., prior to consumption. Occasionally coquina clams are eaten raw by epicurean beachcombers.

Eight species of cestodes were recovered from these seven edible pelecypods and their infection data are summarized in Table 3. One should note that the larvae of *Tylocephalum* sp. and *Parachristianella* sp. were the most prevalent in that group. *Tylocephalum* larvae occurred in all seven pelecypods. Bay scallops were infected by the largest number of species, seven, while oysters contained only one species.

The seven pelecypods cited above do not constitute the only edible mollusks that harbor larval cestodes. According to Euell Gibbons (1964), mollusks of 14 additional (infected) genera and/or species that occur in the Gulf are edible. These include the fulgur whelks, *Busycon contrarium* (Conrad) and *B. spiratum* [subspecies *pyruloides* (Say)]; the slipper shells, *Crepidula* spp., the Atlantic moon snail, *Polinices duplicatus* (Say); the rock shells, *Thais* spp.; the pen shells, *Atrina* spp. and *Pinna carnea* Gmelin; the venus clams, *Chione* spp.; angel wing clams, *Cytopleura costata* (Linné); the cockles *Dinocardium robustum* (Lightfoot), *Trachycardium egmontianum* (Shuttleworth), and *Laevicardium* spp.; the jackknife clams, *Ensis* spp.; the mussels, *Modiolus* spp.; and the tagelus clams; *Tagelus* spp. Gunter (1971) listed eight additional (infected) edible or potentially edible Gulf mollusks including the cancellate cantharus, *Cantharus cancellarius* (Conrad); the banded tulip snail, *Fasciolaria lilium hunteria* (Perry) (as *F. hunteria*); the giant eastern murex, *Murex fulvescens* Sowerby; the lettered olive, *Oliva sayana* Ravenel; the half-naked pen shell, *Atrina seminuda* (Lamarck); the disk clam, *Dosinia discus* (Reeve); the Florida lucine, *Pseudomiltha floridana* (Conrad) (as *Lucina f.*); the ponderous ark, *Noetia ponderosa* (Say); and the stout tagelus clam, *Tagelus plebeius* (Lightfoot). The larval cestode parasites of these edible mollusks are presented in Table 2.

Seven additional potentially edible (and infected) pelecypods are included in Table 2 because of their abundance and fleshy appearance or because they are congeners of edible species. Notable among this group are the princess venus clam, *Periglypta listeri* (Gray), the calico clam, *Macrocallista maculata* (Linné), and the Atlantic thorny oyster, *Spondylus americanus* Hermann.

Prehistoric aboriginal inhabitants of the eastern Gulf coast harvested and consumed numerous species of molluscan

TABLE 3.

Larval cestode infection data from seven edible Pelecypods of the eastern Gulf of Mexico.

Infected Mollusk Species	Larval Cestode Species: (No. Infected Mollusks/No. Larvae/No. Stations)								Total Number of Mollusks/ Stations
	Acanthobothrium (Harry)	*Anthobothrium* sp.	*Rhinebothrium* sp.	Unidentified Tetraphyllidean*	*Eutetrarhynchus* sp.	*Parachristianella* sp.	*Polypocephalus* sp.	*Tylocephalum* sp. (Burton)	
Argopecten irradians concentricus (Say)	1/1/1	1/1/1	67/1,460/8	1/3/1	2/3/1	42/222/3	42/777/4	68/5,639/8	78/11
Crassostrea virginica (Gmelin)								60/950/13	138/20
Donax variabilis Say			23/35/2			5/6/1		1/1/1	120/3
Macrocallista nimbosa (Lightfoot)		1/1/1				60/1,674/7		39/462/7	69/9
Mercenaria campechiensis (Gmelin)								6/101/5	26/10
Mercenaria mercenaria texana (Dall)								3/477/2	4/2
Spisula solidissima similis (Say)		1/1/1	23/77/2			30/520/2		8/42/1	35/3

*Probably unfacetabulo-plerocercoids of *Rhinebothrium* sp.

shellfish that are now known to harbor larval cestodes. Archaeological data from kitchen middens or garbage mounds at 32 coastal sites west of the Aucilla River in the Florida panhandle indicate that coastal Indians consumed and/or utilized the shells of at least 18 species of marine gastropods and 15 species of marine pelecypods (Willey 1949; Percy 1973). In some middens 95% of the faunal remains consisted of mollusk shells. Larval cestodes presently infect nine of those gastropods and eleven of those pelecypods (Table 2).

Only five potentially edible mollusks listed by Gibbons (1964) and Gunter (1971) appear to be devoid of larval cestodes. This may be misleading because of the small sample size (ten or fewer specimens were examined). These include the Atlantic ribbed mussel, *Geukensia demissa granosissima* (Sowerby) (syn. *Modiolus demissus granosissimus*); the hooked mussel, *Ischadium recurvum* (Rafinesque) (syn. *Brachidontes recurvus*); the tulip mussel, *Modiolus americanus* (Leach); and the frons oyster, *Lopha frons* (Linné) (syn. *Ostrea frons*).

All of the cestodes found in edible or potentially edible mollusks of the eastern Gulf utilize elasmobranch fish (sharks, skates or rays) as final hosts and probably will not develop in humans that consume viable larvae. The majority of the cestodes were confined to the mollusk's visceral region and those tissues are usually separated from the edible portion, during processing, and discarded. Those cestodes that remain in the edible portion, or in mollusks that are prepared whole, are destroyed by the cooking process. The *Tylocephalum* larvae that are ingested by humans who consume raw (living) oysters, coquina clams or other infected pelecypods, are not known to be infective. Experimental evidence obtained during this study suggests that those larvae are destroyed by human digestive acids and enzymes. While attempting to remove individual *Tylocephalum* larvae from small pieces of oyster tissue via digestion (*in vitro*), I found that a 1% solution of hydrochloric acid and pepsin in seawater would kill all encysted larvae in a short period of time.

Larvae of *Tylocephalum* sp. (Burton 1963) were the most abundant, widely distributed, and least host-specific of all cestodes that infected edible mollusks. They occurred in all but three of the 43 infected mollusks covered in this report. They were found in mollusks from every type of estuarine and marine habitat sampled and were distributed from the Mississippi Sound to the Florida Keys. Plerocercoids of *Rhinebothrium* sp. (Cake 1975) were the next most abundant larval forms; they occurred in 24 of 43 infected mollusks from every type of marine habitat between the Mississippi Sound and the Florida Keys. Three other cestodes, *Parachristianella* sp. (Cake 1975) (15 of 43), *Eutetrarhynchus* sp. (Cake 1975) (11 of 43), and *Acanthobothrium* sp. (Regan 1963) (10 of 43) were common parasites of edible mollusks, but were restricted to fewer habitats, smaller geographic ranges, and occurred in smaller numbers of infected hosts. The remaining cestode species exhibited more host-specificity, but were restricted to fewer habitats and smaller geographical ranges. The larvae of *Polypocephalus* sp. (Cake 1975) occurred only in bay scallops, *A. i. concentricus*, and only in shallow bays adjacent to the Apalachicola River in northwest Florida.

DISCUSSION

The most important consequence of larval cestode infections in edible mollusks is the effect that those infections, especially heavy infections, have on the health of the host. Heavy infections certainly cause physiological stress which may affect growth, reproduction, and edibility. Heavy infections of *Parachristianella* sp. in sunray venus clams, *M. nimbosa*, severely restrict the passage of food material through the host's intestine. Sparks (1963) suggested that heavy *Tylocephalum* infections in oysters, *C. virginica*, at West Loch, Pearl Harbor, Hawaii, were responsible for the low condition index, a measure of fatness or marketability, that he observed. [Condition Index = Dry meat weight (gm) X 100/Shell volume (ml).] Wolfe (1976) noted the presence of heavy *Tylocephalum* infections in Sidney rock oysters, *Saccostrea* (syn. *Crassostrea*) *commercialis* Iredale and Roughley, from northern Australia. He suggested that the physiological stress caused by the infections produced the "poor, transparent, and watery" conditions noted in all infected oysters.

Pelecypods appear to serve as primary intermediate hosts while molluscivorous gastropods appear to serve as secondary intermediate or paratenic (transport) hosts for these larval cestodes. Most of the molluscan hosts are confirmed prey of demersal elasmobranchs of the Gulf of Mexico. Pelecypods and filterfeeding, herbivorous and omnivorous gastropods (e.g., *Crepidula* spp.) become infected by ingesting reproductive products (e.g., eggs and gravid proglottids released by the definitive hosts) or free-swimming coracidia. Molluscivorous gastropods become infected by ingesting infected pelecypods or gastropods. The first infection mode is based on circumstantial feeding and infection information (Cheng 1966), and the second mode was demonstrated during this investigation. Cheng found coracidia of *Tylocephalum* sp. in the digestive tract and intimately associated with the gills of *Tylocephalum*-infected oysters, *C. virginica*. Banded tulips, *F. l. hunteria*, infrequent hosts of *Rhinebothrium* sp. (Cake 1975), exhibited statistically significant increases in total numbers of larvae when fed *Rhinebothrium*-infected ponderous arks, *N. ponderosa* (unreported data).

Only one larval cestode, *Dioecotaenia cancellata* (Linton), could be identified to species, while the remainder were identified only to a generic level because they lacked definitive, adult characteristics. Four larval species, *Acanthobothrium* sp. (of Regan), *Acanthobothrium* sp. (of Harry) *Rhinebothrium* sp. (of Cake), and *Polypocephalus* sp. (of

Cake), were identified as a result of incubation experiments using an artificial elasmobranch saline solution (Read et al. 1960; Hamilton and Byram 1974). Considerable research, including improved infection and incubation experiments, needs to be conducted before these larval forms can be identified completely or described as new species.

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A Checklist of the Ahermatypic Scleractinia of the Gulf of Mexico, with the Description of a New Species

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A CHECKLIST OF THE AHERMATYPIC SCLERACTINIA OF THE GULF OF MEXICO, WITH THE DESCRIPTION OF A NEW SPECIES

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ABSTRACT A brief chronology of discovery of the 54 ahermatypic Scleractinia known from the Gulf of Mexico is presented. Of this total, 6 are new records for the Gulf. A checklist is provided for all species indicating their Gulf distribution and their overall bathymetric range. One new species of *Pourtalosmilia* is described, which represents a new record for this genus in the western Atlantic.

INTRODUCTION

Ahermatypic Scleractinia from the Gulf and Caribbean were systematically collected aboard the U. S. Coast Survey Steamers "Corwin," "Bibb," and "Blake," and studied by Pourtalès between 1867–1880. Pourtalès (1867) reported the first ahermatypic corals from stations occupied by the "Corwin" in the Gulf off Havana, Cuba: *Caryophyllia berteriana* and *Enallopsammia profunda*. After more extensive dredging by the "Bibb," mainly off the Tortugas and Key West, Florida, Pourtalès (1871) reported an additional 13 species from these areas. Finally, as the result of 86 stations occupied by the "Blake," from localities north of the Yucatan Peninsula, off northwestern Cuba, and the west coast of Florida, he (Pourtalès 1878) added another 19 species to the Gulf fauna. "Blake" station 50 is discounted because of ambiguous locality data.

No additional species of ahermatypes were reported until Whitten, Rosen and Hedgpeth (1950) listed *Astrangia astreiformis* from the Texas coast in a preliminary survey of that area.

Moore and Bullis (1960) were the first to report *Lophelia prolifera* from the Gulf about 65 km east of the mouth of the Mississippi River. They estimated that this species formed banks over a kilometer long and 55 m thick at depths of 371–512 m.

In their listing of benthic invertebrates of the eastern Gulf of Mexico, Collard and D'Asaro (1973) listed five more species for the Gulf fauna based on implied records found in Vaughan and Wells (1943). D'Asaro (pers. comm.), however, collected only two of these species from the Gulf: *Astrangia solitaria* and *Phyllangia americana*. Both Tresslar (1974) and Keller (1975) recorded ahermatypes from the Gulf but did not establish new records.

In his unpublished dissertation, Cairns (1976, appendix II) listed 21 species of deep-water ahermatypes from the Gulf of Mexico, four of which were new records for the Gulf. Based on additional material collected by the Florida Department of Natural Resources in Project "Hourglass," Cairns (1977) listed 36 ahermatypic species from the Gulf, six of which were new records for the Gulf. This paper lists six additional ahermatypic species, increasing the total number of ahermatypes known from the Gulf to 54.

MATERIAL AND METHODS

The data that form the basis of the checklist were obtained from the literature cited in the introduction. Unfortunately, Pourtalès rarely indicated the station number at which a specimen was collected. It is therefore necessary to consult a detailed station list (Smith 1889) and see the original material to compensate for junior synonyms, misidentifications and split lots. The distribution and identification of every species were verified by the author, either from the original material or from subsequently collected specimens. The specimens on which the new records are based were among approximately 500 specimens on loan from Dr. Linda H. Pequegnat and Mr. Jack H. Thompson (Texas A&M University), and numerous specimens collected primarily by the "Oregon" and "Silver Bay" in the NMNH collections.

The southeastern limits of the Gulf of Mexico are defined as the line connecting Key West, Florida to the closest point of the Cuban coast (approximately 81°48′W) and the shortest line between western Cuba and northeastern Yucatan, Mexico. Species occurring primarily outside of the Gulf of Mexico but which have been collected from the western Straits of Florida at the edge of their ranges are not included in the checklist. These species are *Fungiacyathus symmetricus, Anthemiphyllia patera, Caryophyllia antillarum, Deltocyathus agassizi, Trochocyathus recurvatus, Trochocyathus cylindraceus, Desmophyllum cristagalli, Thalamophyllia riisei, Peponocyathus folliculus, "Rhizotrochus" tulipa, Gardineria minor, "Ceratotrochus" hispidus, Balanophyllia cyathoides,* and *Enallopsammia rostrata.*

The Gulf is further subdivided into six areas (Figure 1)

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to facilitate geographic categorization: (1) from the Florida Keys to Apalachee Bay, Florida; (2) from Apalachee Bay to the Mississippi River Delta; (3) from the Delta to the Texas-Mexico border; (4) from that border to the Tabasco-Campeche, Mexico border; (5) the Campeche Bank; and (6) the Yucatan Channel and off northwestern Cuba to 81°48′W.

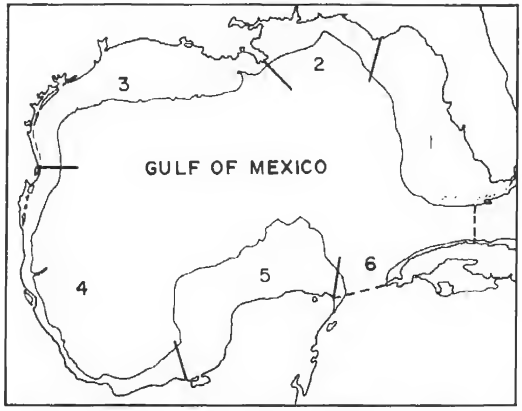

Figure 1. Map of the Gulf of Mexico showing the six geographic subdivisions used in this paper. The 100 fm contour is included.

CHECKLIST

Distributional records (Table 1) are those for the Gulf of Mexico only; however, depth ranges provided are for the species throughout its range. Descriptions, photographs, and complete geographic ranges for most of these species are in Cairns (1976). An asterisk (*) denotes a new record for the Gulf of Mexico. The number one in parentheses (1) indicates that this species is known from only one Gulf record. This list is far from comprehensive, since little collecting has been done in areas 4 and 6. Inevitably more ahermatypic species will be discovered in the Gulf and distributional gaps will be filled in.

TABLE 1.

Checklist and distributions of ahermatypic Scleractinia known from the Gulf of Mexico

	Geographic Area 1	2	3	4	5	6	Depth Range (meters)
Order: Scleractinia							
Suborder: Astrocoeniina							
Family: Pocilloporidae							
Madracis myriaster (Milne Edwards & Haime, 1849)	X	X	X			X	37 – 875
Madracis asperula Milne Edwards & Haime, 1849	X		X			X	24 – 200
Suborder: Fungiina							
Family: Fungiidae							
Fungiacyathus crispus (Pourtalès, 1871)	X	X					183 – 1010
Suborder: Faviina							
Family: Faviidae							
Cladocora debilis Milne Edwards & Haime, 1849	X					X	11 – 150
Family: Rhizangiidae							
Astrangia astreiformis Milne Edwards & Haime, 1849	X	X	X				10 – 29
Astrangia solitaria (Lesueur, 1817)	X	X					0.3 – 43
Phyllangia americana Milne Edwards & Haime, 1849	X	X					0.3 – 40
Family: Oculinidae							
Oculina tenella Pourtalès, 1871	X					X	67
Madrepora oculata Linnaeus, 1758			X	X		X	80 – 1500
Madrepora carolina (Pourtalès, 1871)	X	X	X			X	53 – 1003
Suborder: Caryophylliina							
Family: Caryophylliidae							
Caryophyllia sp. cf. *C. ambrosia* Alcock, 1898	X	X	X	X	X	X	183 – 2360
Caryophyllia cornuformis Pourtalès, 1868	X					X	137 – 931
Caryophyllia berteriana Duchassaing, 1850	X	X			X	X	100 – 850
Caryophyllia polygona Pourtalès, 1878					X	X	715 – 1817
Caryophyllia horologium Cairns, 1977	X		X				55 – 100

TABLE 1 – Continued

	Geographic Area 1	2	3	4	5	6	Depth Range (meters)
Caryophyllia maculata (Pourtalès, 1874)	X						3 – 161
**Oxysmilia rotundifolia* (Milne Edwards & Haime, 1849)			X			X	46 – 640
"Trochocyathus" flos (Pourtalès, 1878)		X				X	22 – 560
Trochocyathus rawsonii Pourtalès, 1874	X				X	X	131 – 622
Puracyathus pulchellus (Philippi, 1842)	X	X	X		X	X	25 – 838
"Thecocyathus" laevigatus Pourtalès, 1871	X					X	183 – 576
Deltocyathus italicus (Michelotti, 1838)	X	X		X		X	403 – 2634
Deltocyathus calcar Pourtalès, 1874	X	X			X	X	101 – 675
Deltocyathus hexagonus (Gravier, 1915)	X	X			X	X	183 – 910
**Stephanocyathus (S.) diadema* (Moseley, 1876)		X	X		X	X	795 – 2133
**Stephanocyathus (S.) paliferus* Cairns, 1977	X				X	X	229 – 1158
**Stephanocyathus (O.) coronatus* (Pourtalès, 1867)		X			X	X	543 – 1280
Turbinolia corbicula Pourtalès, 1878						X	400 – 576
Peponocyathus stimpsonii (Pourtalès, 1871)	X				X	X	110 – 293
Sphenotrochus sp.	X(1)						15
Lophelia prolifera (Pallas, 1766)		X				X	60 – 2170
Anomocora fecunda (Pourtalès, 1871)	X				X	X	73 – 567
Coenosmilia arbuscula Pourtalès, 1874	X				X	X	109 – 807
Dasmosmilia variegata (Pourtalès, 1871)	X						185 – 600
Dasmosmilia lymani (Pourtalès, 1871)		X				X	33 – 366
Solenosmilia variabilis Duncan, 1873						X	220 – 3383
Asterosmilia prolifera (Pourtalès, 1871)		X			X		32 – 311
**Pourtalosmilia conferta* n. sp.		X(1)					55 – 191
Family: Flabellidae							
Flabellum moseleyi Pourtalès, 1880	X	X				X	216 – 1097
Flabellum fragile Cairns, 1977	X				X		80 – 366
Javania cailleti (Duchassaing & Michelotti, 1864)	X	X			X	X	86 – 2165
"Rhizotrochus" fragilis Pourtalès, 1868	X				X	X	90 – 796
Gardineria simplex (Pourtalès, 1878)						X(1)	12 – 183
Family: Guyniidae							
Guynia annulata Duncan, 1872	X	X	X		X	X	3 – 653
Schizocyathus fissilis Pourtalès, 1874	X	X				X	88 – 640
Stenocyathus vermiformis (Pourtalès, 1868)	X					X	128 – 1229
Suborder: Dendrophylliina Family: Dendrophylliidae							
Balanophyllia floridana Pourtalès, 1868	X	X				X	37 – 183
Balanophyllia palifera Pourtalès, 1878						X	53 – 708
Dendrophyllia cornucopia Pourtalès, 1871	X					X	132 – 960
**Dendrophyllia alternata* Pourtalès, 1880			X				276 – 1200
Enallopsammia profunda (Pourtalès, 1867)	X					X	146 – 1748
Bathypsammia tintinnabulum (Pourtalès, 1868)	X					X	210 – 1079
"Rhizopsammia" manuelensis Chevalier, 1966		X	X				55 – 366
Trochopsammia infundibulum Pourtalès, 1878						X(1)	532 – 1472

SYSTEMATIC ACCOUNT

Order Scleractinia Bourne, 1900
Suborder Caryophylliina Vaughan and Wells, 1943
Family Caryophylliidae Gray, 1847
Subfamily Parasmiliinae Vaughan and Wells, 1943
Genus *Pourtalosmilia* Duncan, 1885

The genus *Pourtalosmilia*, previously considered to be a junior synonym of *Anomocora* Studer, 1878, was resurrected by Zibrowius (1976) for the eastern Atlantic *P. anthophyllites*. The following records are the first for this genus in the western Atlantic.

Pourtalosmilia conferta, n. sp.
(Plate 1, Figures 1–6)

Material Examined. USNM 46851, Holotype colony; USNM 46852, Paratypes, 2 large colonies and 5 pieces, R/V "Silver Bay" 5660, 34°57.5'N, 75°19.5'W, 119–173 m, 14 April 1964; USNM 46853, 6 Paratypes, M/V "Silver Bay" 332, 29°17'N, 88°16'W, 84 m, 24 March 1958; USNM 46854, 6 Paratypes, R/V "Gerda" 134, 24°29'N, 80°53'W, 191 m, 21 June 1963; USNM 46855, 1 Paratype, 79°58.0'N, 27°51.8'W, 83 m, (collected by W. Jaap); USNM 46856, 2 Paratypes, M/V "Albatross" III, 18 miles off Cape Lookout, North Carolina, 55 m, 12 February 1950; USNM 46857, 18 Paratypes (dead), "Chain" cruise 35, station 15, 0.5–0.7 miles east of St. Paul Rocks, Brazil, 291 m, 13 April 1963; USNM 46858, 10+ Paratypes, "Chain" cruise 35, station 16, 0.6–0.4 miles southeast of St. Paul Rocks, Brazil, 110–146 m, 13 April 1963; off Ilha Raza de Guaratiba, Brazil, near 23°05'N, 43°34'W, depth unknown, 17 July 1959, deposited at Station Marine d'Endoume, Marseille; south of Cape Hatteras, North Carolina, 35° 15.8'N, 76°02'W, 82–100 m (collected by I. Macintyre, No. 8234), deposited at Cornell University.

Description. This species forms large, densely-branched colonies that result primarily from extratentacular budding from the edge zone. However, intratentacular budding also occurs. The subcylindrical corallites may continue to grow even after budding several new corallites, and attain lengths up to 60 mm. Adjacent corallites often anastomose laterally, which produces a very compact corallum with small cavities throughout. These cavities often provide niches for various bivalves, bryozoa, and polychaetes. The largest colony examined measures 22 cm tall and 19 cm in diameter, weighing 1.5 kg (dry skeleton). Calices are round to elliptical; an average adult calice measures between 7.5–11.0 mm in diameter. The coenosteum is covered by uniform, fine, round granules that produce a smooth texture. Sometimes very faint intercostal striae are present near the calice, but in general, costae are not evident.

The septa are arranged in six systems and four cycles, rarely exceeding 48 in number. S_1 and S_2 are equal in size, slightly exsert and have straight, vertical inner edges that do not reach the columella. S_3 are slightly smaller and have wavy lower inner edges. S_4 are the smallest septa and have straight inner edges. In one particularly large calice (calicular diameter = 12.0 mm) there are 72 septa arranged in 18 half-systems instead of 13 pairs of smaller S_5 arranged within the first 12 half-systems. The septal granulation is variable, ranging from low, pointed spines to tall, blunt granules. The lower, inner edges of the S_3 often bear short carinae oriented perpendicular to the septal edge.

Large, prominent pali, usually forming a distinct crown, are arranged before the S_3. The fossa is fairly deep and contains a large fascicular columella composed of twisted ribbons, which may stand alone or be solidly fused to one another in a spongy mass. Widely spaced, endothecal dissepiments are abundant.

Discussion. *Pourtalosmilia conferta* is very similar to *P. anthophyllites* (Ellis and Solander, 1786) (Plate 1, Figure 7), which is known only from the eastern Atlantic (Zibrowius 1976). They are distinguished primarily on the basis of their pali. The pali of *P. anthophyllites* are often poorly defined or absent, not separated by a distinct notch from their septa, and sometimes identical in structure to the columellar elements, rarely forming a distinct palar crown. Those of *P. conferta* are usually well-defined, separated from their septa by a deep and narrow notch, always structurally distinct from the columella, and usually forming a distinct palar crown. Also, *P. conferta* usually has a complete fourth cycle of septa (48 septa) and sinuous inner edges to the S_3, whereas *P. anthophyllites* often has less than 48 septa (9–11 half-systems) and straight inner edges to the S_3.

Etymology. The specific name *conferta*, meaning crowded or thick, pertains to the densely-branched colonial habit of the species.

Type – Locality. Off Cape Hatteras, North Carolina: 34°57.5'N, 75°19.5'W, 119–173 m.

Geographic Distribution. Off Cape Hatteras; Florida east coast; Pourtalès Terrace, Straits of Florida; off Mississippi, Gulf of Mexico; St. Paul Rocks; off Rio de Janeiro, Brazil.

Bathymetric Range. 55–191 m.

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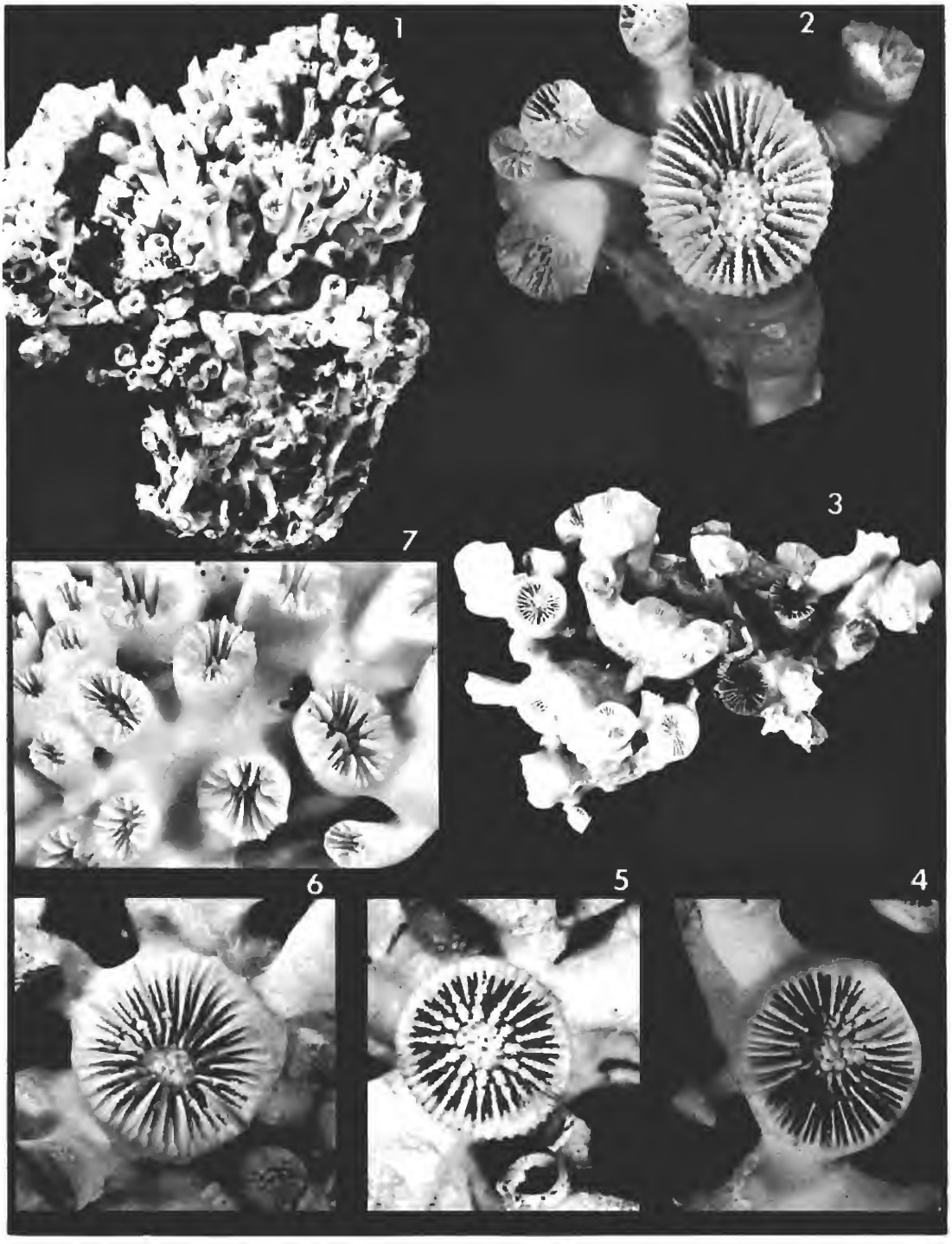
PLATE 1

CAPTIONS

1. *Pourtalosmilia conferta* (holotypic colony): "Silver Bay" 5660, X 0.5, USNM 46851.
2. *P. conferta* (paratype): off Cape Lookout, North Carolina, X 4.5, USNM 46856.
3. *P. conferta* (paratype): "Silver Bay" 332, X 0.9, USNM 46853.
4. *P. conferta* (paratype): "Silver Bay" 332, X 3.0, USNM 46853.
5. *P. conferta* (paratype): off eastern Florida, X 4.5, USNM 46855.
6. *P. conferta* (paratype): off Ilha Raza de Guaratiba, Brazil, X 2.7, deposited at Station Marine d'Endoume, Marseille.
7. *P. anthophyllites:* 38°16.8′N, 8°56.4′W, 250–300 m, X 4.0, deposited at Station Marine d'Endoume, Marseille.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Location of the Mississippi Sound Oyster Reefs as Related to Salinity of Bottom Waters During 1973-1975

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LOCATION OF THE MISSISSIPPI SOUND OYSTER REEFS AS RELATED TO SALINITY OF BOTTOM WATERS DURING 1973–1975[1]

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ABSTRACT The relationship of producing natural oyster reefs of Mississippi Sound to the salinity regime of bottom waters is investigated. Extreme and average conditions were extracted from data taken at 87 stations over a 21-month period from June 1973 through February 1975. With one exception, the producing reefs were subjected to salinity minimums of 2.0 to 4.0 parts per thousand (ppt), maximums of 18.0 to 22.0 ppt, with average conditions being between 10.0 and 16.0 ppt. Salinity-suitable areas in the Sound not now inhabited by oysters are described.

INTRODUCTION

Salinity plays an important role in the distribution, migration, growth and reproductive processes of most marine species (Pearse and Gunter 1957). The tolerance of the animals to normal fluctuations of salinity in the ambient waters depends largely upon the species' osmotic regulatory ability (Gunter et al. 1973). Thus, the absence or presence of salt in sufficient quantity constitutes a physiological barrier to most fresh, brackish or oceanic-water species. Motile forms, unless trapped, can usually avoid waters having salinity concentrations outside their tolerance levels. Less motile and sessile forms must employ other protective mechanisms or die.

The oyster *Crassostrea virginica* comprises the staple of the oyster fishery of Mississippi Sound and contiguous water bodies. The historically productive reefs of the Sound have evolved partly because of a satisfactory salinity regime. It appears reasonable that if the salinity regimes of the bottom waters over productive reefs were known, this information could be used to help identify other suitable areas for oyster cultivation. The objectives of this paper are to show the distribution of the average and extreme salinity levels observed in Mississippi Sound bottom waters over a 21-month period and to discuss the location of productive oyster reefs within this salinity regime. In Mississippi, where state law now permits the leasing of state water bottoms for the cultivation of oysters, site location relative to salinity will probably be a major factor in the outcome of the venture.

Crassostrea virginica is a brackish-water animal that can tolerate wide fluctuations in salinity; however, there are limits beyond which salinity must not go if the oyster is to remain alive, reproduce and "fatten" (Engle 1948). Gunter (1950) stated that oysters can survive a salinity as low as 2.0 ppt for about a month and can even survive in fresh water for several days. The experiments of Amemiya (1926) showed the upper and lower salinity limits of *C. virginica* to be 39.0 ppt and 1.5 ppt, respectively. In a series of experiments designed to determine the effects of salinity variations on oysters, Loosanoff and Smith (1949) found that fresh water conditions were not as detrimental to oysters acclimated to lower salinities as to those accustomed to higher salinity levels.

The influx of fresh water has been reported as a major cause of oyster mortality by many authorities: Ritter (1895), Cary (1906a, 1906b), Moore (1913), Galtsoff (1930, 1931), Lunz (1938), Viosca (1938), Engle (1946), Hopkins (1946), Gowanloch (1946), James (1946), Truitt (1946), Butler (1949, 1952), Gunter (1953), Beaven (1955) and Andrews et al. (1959). In addition, the oyster is prey to the conch *Thais haemastoma* especially when salinities rise above 12.0 ppt (Gagliano et al. 1970). Gunter (1950), referring to his unpublished experiments, stated that this predator dies at salinities between 10.0 and 8.0 ppt. The author, from personal observations over many years, can attest to the efficiency of *T. haemastoma* in the decimation of local reefs.

AREA DESCRIPTION

Mississippi Sound is a relatively shallow (3.05 m), elongate (128.3 km) body of water with an average width of 15.3 km. Its curvate major axis is aligned in approximately an east-west direction. The Sound is bounded on the north by the states of Mississippi and Alabama, on the east by Mobile Bay, on the west by Lake Borgne and on the seaward southern boundary by the Gulf of Mexico from which it is partly separated by a series of barrier islands. The distribution of bottom sediments has not been completely mapped for the area. However, charts prepared by Otvos (1976) show the existence of an irregular pattern of sediment types. The bottom types associated with oyster reefs in the Sound and bays are muddy fine sand and fine sandy mud. These same bottom types are also extensively present

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in areas not associated with oyster reefs. The producing oyster reefs of Mississippi Sound are shown in Figure 1 (Demoran 1977). The largest reefs lie south and southeast of St. Louis Bay, in Biloxi Bay and near the west mouth of Pascagoula River. Other smaller natural reefs scattered throughout the area do not appear on the chart. Since these reefs only occur in certain areas of the Sound in conjunction with the suitable sediment type, other controlling factors must exist.

The Sound receives fresh water from two major rivers (Pearl, Pascagoula), four minor rivers (Tchouticabouffa, Biloxi, Wolf and Jourdan), numerous tidal bayous and also by direct runoff. Of the minor rivers, the first two empty into upper Biloxi Bay while the latter two discharge into St. Louis Bay. In addition, the western end of the Sound eventually receives the drainage entering Lake Pontchartrain and Lake Borgne.

Only five previous investigations have addressed any aspect of the *in situ* oyster-salinity relationship in Mississippi Sound. Viosca (1938), assessing the effects of the 1937 opening of the Bonnet Carré Spillway on Mississippi Sound marine life, made some general observations. Engle (1948), in assessing the condition of reefs following the hurricane of 1947, noted a westward decline in salinity in Mississippi Sound. Butler (1949, 1952) looked at the effect of the flood of 1945 on local reefs. The study by Gunter (1953) dealt with the effect of lowered salinity on oyster reefs of Louisiana and Mississippi caused by the opening of the Bonnet Carré Spillway in 1950. In any case, the studies were limited to the effect of short-term changes in the salinity levels. Until recent years little was known of the general patterns of salinity in the Sound. Christmas and Eleuterius (1973) combined serially the monthly data and constructed bimonthly charts of salinity distribution for surface and bottom waters. However, these data were often widely separated in both space and time and were thus restricted to expressing general conditions. In 1973, a hydrographic study of Mississippi Sound was initiated. Eleuterius (1976) reported on the temporal and spacial salinity distribution of the Sound. Data on which this analysis is based are from the 1973 study.

METHODOLOGY

Eighty-seven hydrographic stations were established throughout the Mississippi Sound area (Figure 2). The numbering convention utilized was as follows: stations established initially were assigned an odd integer and stations added at a later time were assigned even integers. The number of stations and the vastness of the area precluded covering the entire Sound in a single cruise. The Sound was divided into three overlapping segments that can best be described by their east-west linear extents as follows: the eastern segment extended from the west tip of Dauphin Island to the east tip of Ship Island; the middle section covered the area from the west end of Horn Island to near the west end of Cat Island; and the western section extended from near the west end of Cat Island to just west of Half Moon Island. The three sections were overlapping in that stations on boundaries common to adjacent sections were occupied when cruises were conducted in either of the adjoining areas. Cruises were conducted approximately semimonthly in the eastern section from 14 June 1973 through 1 July 1974; in the middle section from 5 February 1974 through 25 February 1975; and in the western section from 1 March 1974 through 19 February 1975.

Conductivity measurements, later converted to salinity, were made by a temperature-compensated Martek, Model II system. The accuracy of the instrument in measuring conductivity is reportedly ±0.2 mmho/cm and less than ±0.1°C for temperature. The near-bottom measurements were always taken within 0.75-meter of the bottom.

For each station the minimum and maximum salinity levels encountered were determined and the average computed from the set of observations. Isohaline charts were constructed for each of the extremes and the average condition by employing linear interpolation to determine the path of the isopleths.

Only during a four-month period (February 1974 – May 1974) was sampling conducted simultaneously in all three sections of the Sound. By excluding this time period and comparing river flows (U.S. Department of the Interior 1973, 1974, 1975) of Pearl River located near the western end with Pascagoula River in the east, some clarification can be made of the vagaries of combining data offset in time from the different sections. For the period June 1973 through January 1974 when only the eastern section of the Sound was studied, the ratio of the flow of Pascagoula River to Pearl River was 0.94. When sampling was restricted to only the central and western sections (July 1974 through February 1975), the ratio of Pascagoula River to Pearl River flow became 1.1. Thus, there was a 16-percent change in flow relative to each other between the two time periods when sampling was done exclusively in the eastern and exclusively in the central and western sections. The western section probably experienced slightly higher salinities in the period when efforts were devoted to the eastern section as evidenced by the gauging point on Pearl River at Bogalusa, Louisiana, which showed an increase in flow of less than 0.5 percent over the earlier period. The Pascagoula River gauging station at Merrill, Mississippi, recorded an increased flow (17 percent) during the latter period over the earlier period of the study when sampling had been conducted in the eastern Sound.

Therefore, if sampling had taken place in all sections of

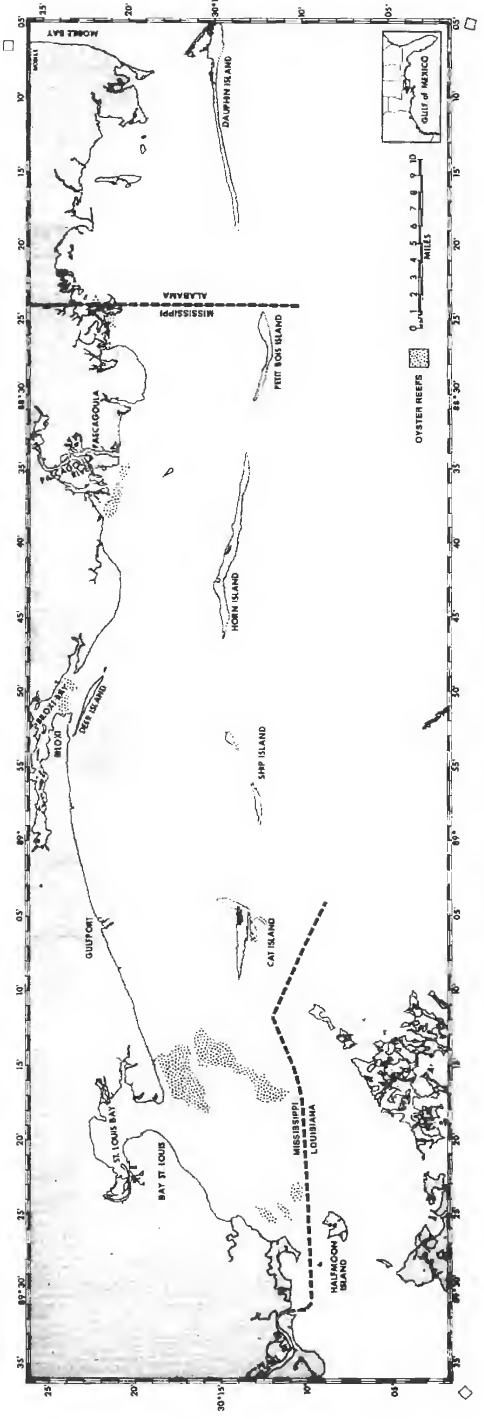

Figure 1. Location of productive natural oyster reefs, Mississippi Sound.

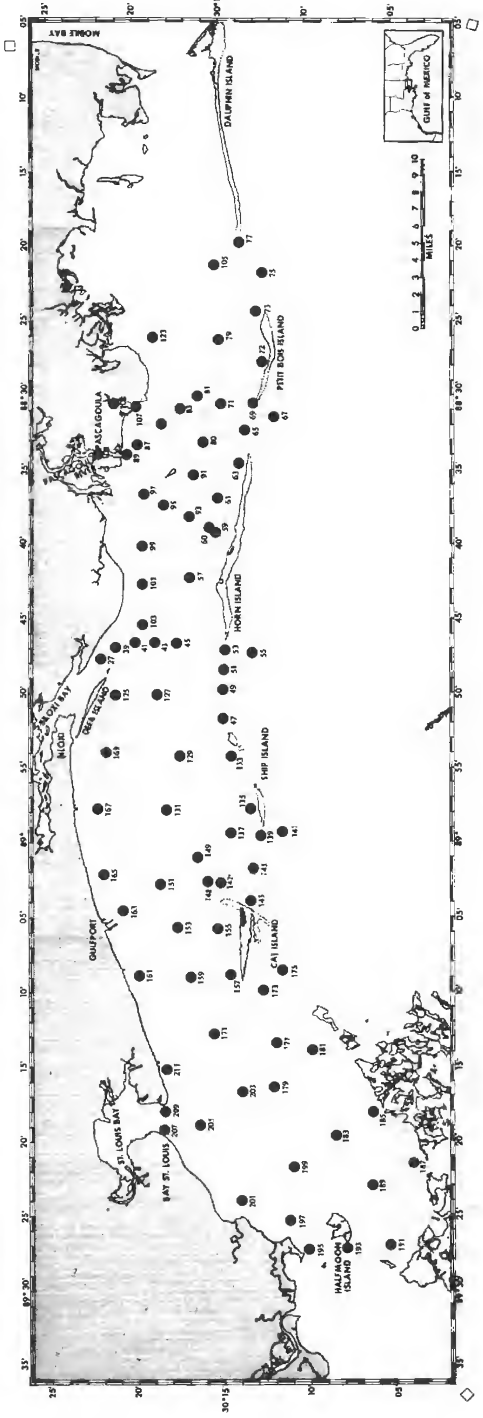

Figure 2. Station Locations, Mississippi Sound area.

the Sound for the entire period of June 1973 through February 1975, the combined data would have shown somewhat higher salinities in the western and central portions and lower salinities in the eastern portion. However, the peak fresh water flow of both rivers lasted less than two months in both years. Since sampling approximated a semimonthly effort and all measurements were given equal weight in the computation of averages, it is unlikely that any notable change would occur in the information presented here. While the salinity data analyzed here are based on a relatively short period of sampling, the general flow patterns implied by the configuration of isohalines are believed to be representative of the Sound waters. It should be pointed out here that the overall salinity of the Sound during this study appears lower than that observed in an earlier investigation (Christmas and Eleuterius 1973). However, since this paper is concerned primarily with relative salinity levels, this is of little importance here.

RESULTS AND DISCUSSION

The isohalines of the salinity-lows (Figure 3) clearly show the influence of the flow of higher salinity Gulf waters into Mississippi Sound through the island passes. The effect is manifested in the form of "tongues" that protrude into the Sound. The northeast-southwest orientation of the isopleths in the western end of the basin, while in this case depicting the lower extreme, is representative of the general pattern repeated in the individual cruises. The areal extent of the fresh water conditions in the western Sound are defined by the 2.0-ppt isohaline. The overall depressed salinity levels extend to the east beyond Cat Island. Therefore, all the major producing reefs experienced salinities between 2.0 and 4.0 ppt. The reefs near the mainland north of Halfmoon Island were probably subjected to almost fresh water.

The area of Mississippi Sound where the minimum levels were highest lies offshore between Gulfport and west Biloxi. Except for direct runoff, this area has no other nearby source of fresh water. The area west of the west mouth of Pascagoula River, known locally as Bellefontaine, is an extensive area that experiences depressed salinity levels attributable to the outflows of Pascagoula River and Biloxi Bay. Only a few scattered oysters exist in this area now. The discharge of the east branch of Pascagoula River mixes rapidly. Its reduced influence is noted by the observation that bottom water of 8.0 ppt never got farther than two miles from the mainland. Higher minimum salinity levels were found, as expected, in and near the ship channels.

Figure 4 depicts the distribution of the highest salinity levels recorded in the Sound's bottom waters. The northeast-southwest orientation of the isohalines again prevails in the western end of the basin. Special note should be made of the limited excursion of the 30.0-ppt water into the Sound through Cat Island Channel (between Cat Island and Louisiana marsh isles). The major oyster reefs south and southeast of St. Louis Bay were exposed to salinity highs between 18.0 and 22.0 ppt. The reefs north of Halfmoon Island did not experience salinities above 18.0 ppt. The area north of Ship Island and Dog Keys passes (between Ship and Horn Islands) is subject to salinities in excess of 30.0 ppt. The high salinities south of Pascagoula are all associated with the deep ship channel. With the exception of localized situations, the waters near the mainland from Gulfport eastward experienced salinity levels in excess of 26.0 ppt.

The distribution of average salinity levels for Mississippi Sound bottom waters is shown in Figure 5. The mean values are higher in or near the ship channels. The isohalines in the western Sound maintain their northeast-southwest orientation indicating that this is the normal pattern. The oyster reefs south and southeast of St. Louis Bay are situated in an area where the average bottom-water salinity is between 10.0 and 14.0 ppt. The average salinity on the reefs north of Halfmoon Island is 9.0 ppt. The mean salinity for Biloxi Bay in the vicinity of the major reefs lies between 14.0 and 16.0 ppt. In the area south of Bellefontaine, which is devoid of natural reefs, the average bottom-water salinity is between 14.0 and 18.0 ppt.

The location of producing oyster reefs in Mississippi Sound appears to be closely associated with a particular portion of the range in salinity. Except for those north of Halfmoon Island and those south and southwest of St. Louis Bay, most oyster reefs are located in bays or near the mainland. With the exception of those reefs north of Halfmoon Island, all of the oyster-producing areas experience similar conditions in salinity as to range and variability.

A previous study (Eleuterius 1976) of the spacial distribution of salinity and flow patterns of the Sound partly substantiated the claim of Engle (1948) that, in general, a decline in salinity exists westward through the Sound. The Pascagoula Ship Channel (depth > 12 m) permits the intrusion of higher-salinity Gulf water up the Pascagoula River where it mixes, thus reducing the fresh or very low-salinity water being discharged directly into the Sound except during periods of peak river flow.

A similar situation exists with the Gulfport Ship Channel which allows the excursion of higher-salinity waters into the Sound than would otherwise occur. However, the presence of this channel is probably of secondary importance to the maintenance of higher-salinity waters in the area, the primary reason for this being the absence of a substantial nearby source of fresh water.

Undiluted high-salinity Gulf waters are restricted from entering the western Sound. Waters exchanged through Cat Island Channel are almost exclusively the estuarine waters of Chandeleur and Mississippi Sounds. Furthermore, the

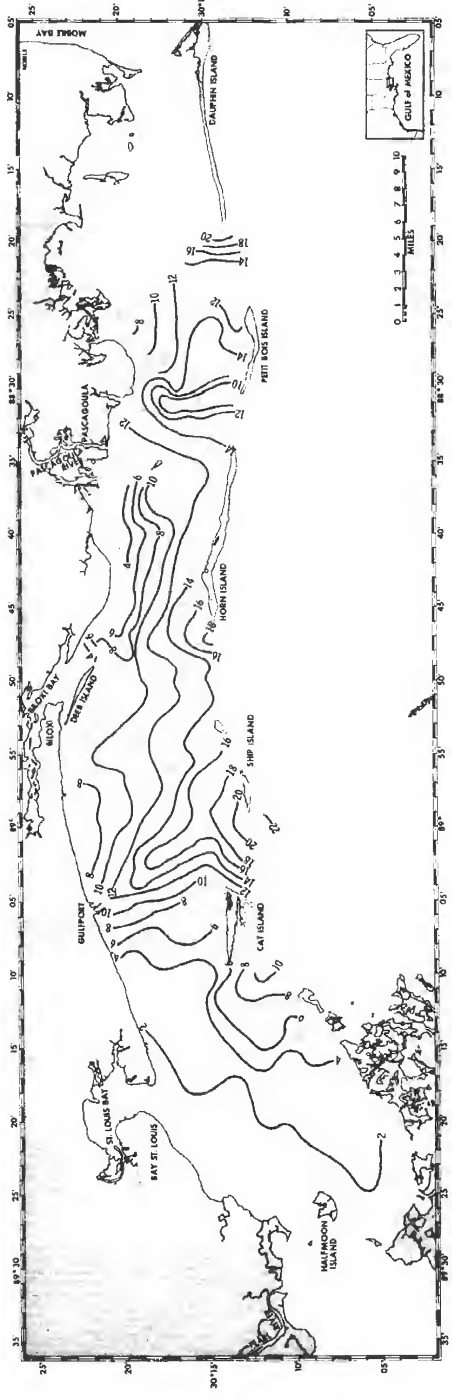

Figure 3. Distribution of minimum levels of salinity (ppt), Mississippi Sound, 1973–1975.

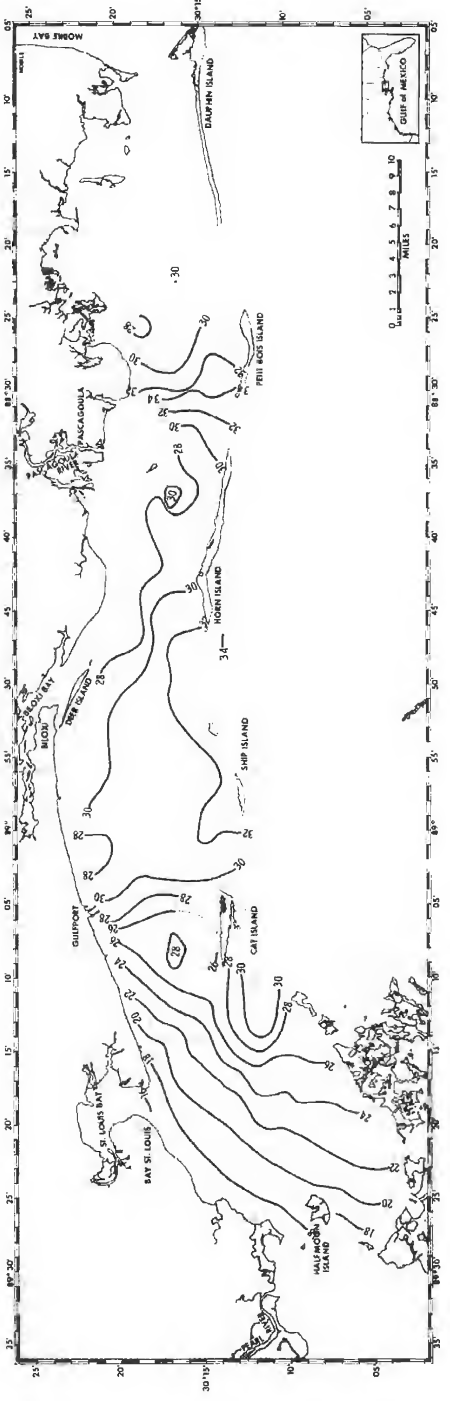

Figure 4. Distribution of maximum levels of salinity (ppt), Mississippi Sound, 1973-1975.

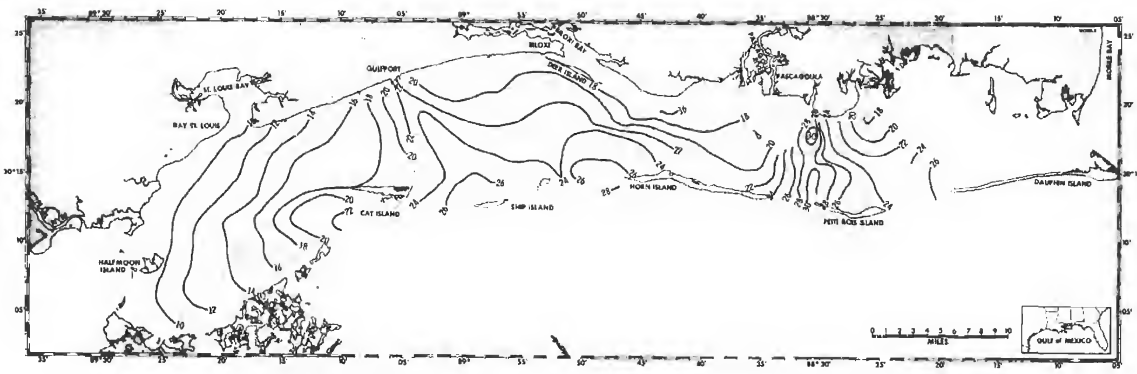

Figure 5. Distribution of average levels of salinity (ppt), Mississippi Sound, 1973–1975.

shallow shoals north of Cat Island Channel block the entry of denser, higher-salinity bottom waters. The combination of receiving the discharge of Pearl River, St. Louis Bay (Wolf and Jourdan Rivers) and Lake Borgne, plus the restricted communication with the open Gulf, is instrumental in maintaining the low-salinity bottom waters.

CONCLUSIONS

The productive oyster reefs of Mississippi Sound, from June 1973 through February 1975, were, in general, subject to salinity minimums of 2.0 to 4.0 ppt, maximums of 18.0 to 22.0 ppt, with average conditions over the reefs being between 10.0 and 16.0 ppt. These findings explain, at least in part, the location of the large reefs in the open area of the western Sound while productive reefs in the remainder of the Sound are found only in bays or very close to the mainland. These areas of the Sound are subject to similar salinity conditions. These remarks are not meant to imply that these specific salinity levels are either optimal or in themselves criteria that can be employed at any time to determine areas suitable for the cultivation of oysters. Rather, it is suggested that within the period of this study, these values could be used to identify areas with similar salinity regimes. While changes in fresh water input, and thus salinity, will occur from year to year, the pattern of flow of bottom waters will vary little. Suitable bottoms where oysters are now absent but have the same favorable salinity conditions as producing areas would seem to be the place where oysters could be successfully cultivated.

The western Sound, which is protected from high-salinity waters because of its limited communication with the open Gulf, shows the greatest potential for oyster cultivation. This region should be considered for future oyster cultivation based on the bottom-water salinity which lies between the 11.0- and 14.0-ppt isohalines of Figure 5. Because of normal low salinity plus the frequency of freshets, Butler (1949) recommended against cultivation of the far western Sound which lies west of these boundaries.

Because of the higher salinity of the central and eastern Sound, there are few areas outside of the existing reefs that appear suitable for oyster cultivation. However, one area that should receive serious consideration is south of Bellefontaine, and other possible sites lie just seaward of the tips of Deer Island. While there may be other areas that would be productive for short periods of time, eventually the oysters probably would succumb to the predator *Thais haemastoma* or, because of persistent low salinities, would not reproduce successfully. When used in conjunction with information on other factors affecting oysters such as bottom type and food supply, the information on the salinity regime of Mississippi Sound bottom waters should reduce the risk in the selection of sites for oyster cultivation.

ACKNOWLEDGMENTS

I wish to express my appreciation to Drs. Harold Howse, Lionel Eleuterius and Gordon Gunter who made many helpful suggestions. Thanks also go to the staff members of the Physical Oceanography Section, Gulf Coast Research Laboratory, who worked with me often under somewhat less than ideal conditions in data collecting; and to Mrs. Joyce Randall Edwards for work in preparation of the typescript of the paper.

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The Effect of Depth on Survival and Growth of Oysters in Suspension Culture from a Petroleum Platform Off the Texas Coast

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Gulf Research Reports, Vol. 6, No. 1, 31–37

THE EFFECT OF DEPTH ON SURVIVAL AND GROWTH OF OYSTERS IN SUSPENSION CULTURE FROM A PETROLEUM PLATFORM OFF THE TEXAS COAST[1]

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ABSTRACT The effect of depth on oysters in suspension culture from a petroleum platform off the Texas coast was monitored for 20 months. Growth and condition was similar for adult oysters cultured at five levels down to 8 m. Oysters had a growth rate of 1.2 mm (level 3) to 1.4 mm (level 1) per month, representing an increase in length of 94% to 150% for the 20 months. The condition was best in June 1973 after five months placement offshore (condition index of 14.8, 15.5, 14.7, 13.5 and 13.2 for levels 1 through 5, respectively). The condition was lowest in June 1974 (2.2, 2.1, 1.3, 1.4 and 1.5 for levels 1 through 5, respectively). Ninety oysters died during the experimental period. Sixty-three percent were from the upper two levels. One hundred forty-five oysters disappeared. Fifty-eight percent were from the bottom two levels. Most oysters disappeared in February 1974 (47% of all disappearances).

INTRODUCTION

The effect of water depth on oyster growth has been little investigated. Oysters are known from a natural, deep water (40 m) reef in Chesapeake Bay (Merrill and Boss 1966). However Gunter and Geyer (1955) noted that *Crassostrea virginica* was limited to the upper few meters of water on petroleum platforms in the Gulf of Mexico off Louisiana and Texas. This was probably not a depth limitation at all, but rather a restriction of the setting oyster larvae to a shallow lens of bay water which floated out to sea (Gunter, personal communication).

In a previous study (Ogle, Ray and Wardle, in press) the growth of oysters in suspension culture for 12 months at two depths in lower Galveston Bay, Texas was compared with the growth of oysters suspended at similar depths from a Texas offshore petroleum platform. Growth in terms of length was comparable at both stations although oysters inshore gained more weight, possibly because that station was ordinarily richer and additionally was in an area receiving municipal pollution. This study, initiated in January 1973, suffered from the loss of the control oysters in the estuary due to vandalism. The oysters on the platform were retained for 20 months to follow growth and survival at depths to approximately 8 meters.

MATERIALS AND METHODS

Studies were conducted at the Atlantic Richfield Company (ARCO) platform B located 6 kilometers offshore from High Island, Texas (Figure 1) in approximately 10 meters of water.

Hydrographic Data

Water samples were taken 1 and 8 meters below the surface with a 250-ml water sampler (constructed of clear plastic tubing and closed by two rubber balls) for determination of hydrographic conditions. Temperatures of the samples were determined with a mercury thermometer to the nearest degree Celsius at the time of collection. Water samples were placed in clear glass 150-ml bottles and transported in a closed wooden case. Salinities were determined to the nearest parts per thousand (ppt) with a refractometer. Samples were refrigerated in the laboratory (ca 1°C) and analyzed within 8 hours from the time of collection for chlorophyll *a* content. After shaking, a 10-ml aliquot of the water sample was extracted according to the procedure of Strickland and Parsons (1968) for chlorophyll *a* determinations. The fluorescence was determined on a Turner Model

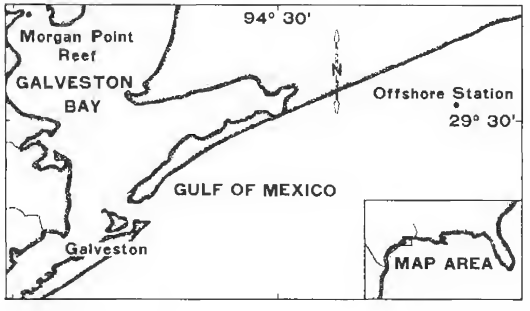

Figure 1. Location of the station in the northwest Gulf of Mexico along the Texas Coast.

[1] Based in part on a thesis submitted to Texas A&M University by John Ogle in partial fulfillment of the requirements for the Degree of Master of Science, May, 1975.

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III Fluorometer having a C-2-60 filter and a door modified for 16 x 125 tubes. The chlorophyll *a* content of the water was calculated in terms of milligrams per cubic meter of seawater.

Hardware

A chain shackled to a cable was passed through the center of 60-cm lengths of 2-cm mesh plastic "Vexar" bagging. A length of brass rod woven through the bag, passed through a link in the chain and bent on both ends was used to hold the bags in place. The bags were folded in the center in a "saddlebag" fashion, each bag containing 10 oysters. The open ends of each bag were closed at the bottom by passing lengths of rod through the mesh and the supporting chain (Figure 2). Ten saddlebags were positioned uniformly along a 6-m length of 95-mm stainless steel cable to which the chain was attached. Three such lengths of cable were attached to the end of a main support cable. Three 1.8-m lengths of 2.5-cm galvanized pipe were used to spread the three cables apart. One pipe was placed at the top, just above the first saddlebag. A second pipe was placed at the bottom below the last saddlebag. A third pipe was clamped midway between the top and bottom pipes. The cable was attached to the main support cable of 127-mm stainless steel wound onto a Beebe No. 10 winch (800-kg capacity) installed in the center of the upper deck of the platform. The entire support apparatus was positioned centrally under the platform by means of 64-mm stainless steel tether cables attached to the platform at three points (Figure 2). The apparatus was lowered into the water so bags were approximately 2 m from the surface and 2 m off the bottom at mean low water. Thus, benthic predators were intended to be excluded from the oyster bags, and the effect of wave action reduced.

Oysters

Collection. Oysters were dredged from a reef on a spoil bank adjacent to the Houston Ship Channel in the vicinity of Morgan Point near Houston, Texas. Oysters were culled to singles and cleaned of all superficial fouling by wire brushing. They were stored for three weeks in a seawater reservoir at the marine laboratory until placement offshore on January 15, 1973.

Placement of Oysters. Saddlebags of oysters were spaced approximately 30 cm apart and occupied approximately 30 cm of a 6-m long cable. Data were obtained by sacrificing samples of oysters. To reduce the number of oysters sacrificed the ten depths were considered as five levels. Mean depths for the levels when suspended were roughly three (1.8–3.0 m), four (3.4–4.3 m), five (4.6–5.5 m), six (5.8–6.7 m) and seven (7.0–7.9 m) meters from the surface. Length, the greatest shell dimension, obtained initially for 60 oysters from the population indicated a size range of 44 to 83 mm (mean 68 mm), 33% of which were of a legal marketable size (76 mm). An attempt was made to place an equivalent total biomass at each of the five levels. Six

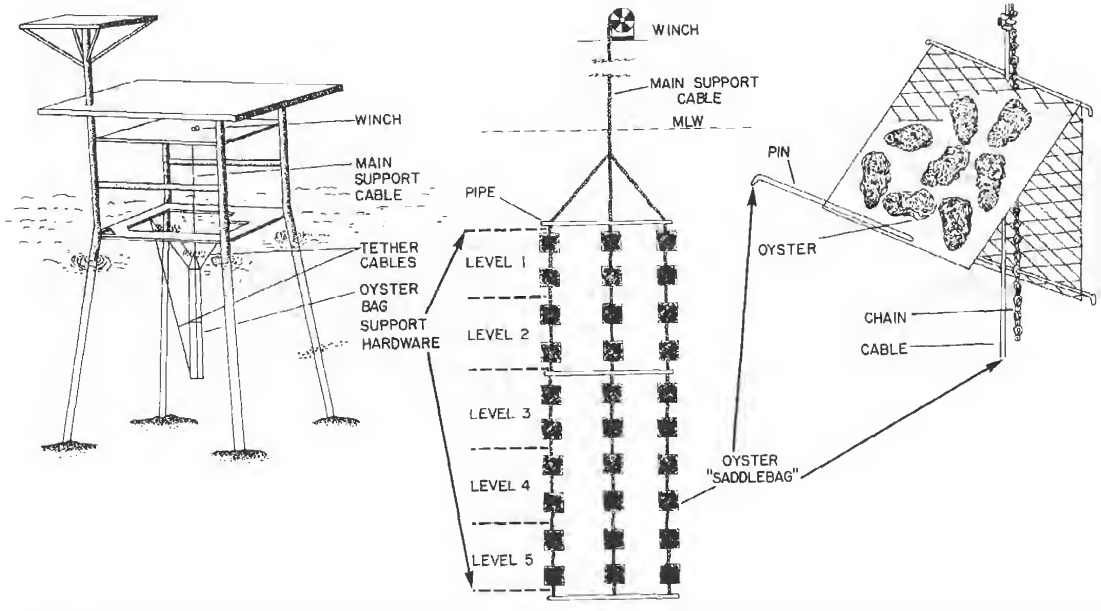

Figure 2. Method of containing oysters in Vexar bags and suspending bags from a petroleum platform offshore from Texas in the Gulf of Mexico

hundred oysters were separated into five groups of 120 oysters ranging in total weight from 10.2 to 10.8 kg. An additional 22 oysters were sacrificed in order to determine the initial level of infection by the fungus *Labyrinthomyxa marina.*

Sampling of Experimental Oysters. Monthly and quarterly samples were taken during a period of 20 months. The number of live oysters and oyster boxes (empty shells) was determined and the mortality calculated every month for oysters at each of the five levels. The monthly mortality of oysters at a level was used to estimate the mortality in oysters missing from the bags. Oysters sampled were considered lost the following month. The estimated mortalities were added to the recorded deaths to derive an adjusted mortality.

Beginning in March 1973, subsamples of ten oysters from each level were removed at quarterly intervals and sacrificed to determine the brushed weight, condition index and level of infection by *L. marina.* The ten oysters were selected to be similar (±17 g) in total fouled weight to the weight of ten average oysters at each level. During June and September 1974 only five oysters were removed due to the few remaining oysters.

Level of infection by the parasite *L. marina* was determined according to the technique of Ray (1952 and 1966). A single piece of the anterior mantle tissue was placed in fluid thioglycollate fortified with antibiotics (mycostatin and chloromycetin) and cultured for 7 days. After culture the tissue was blotted dry, teased, stained with Lugol's Iodine, examined microscopically at 100x and rated for infection intensity according to the procedure of Ray (1954). The weighted incidence (W.I.) was calcualted according to the procedure of Mackin (1962) and the incidence of infection (I.) noted.

An average condition index (CI) was calculated for oysters according to the equation of Hopkins (1949) as follows:

$$CI = \frac{\text{mean dry meat weight in grams}}{\text{volume of shell cavity in milliliters}} \times 100$$

The volume of the shells was determined by water displacement (Galtsoff 1964). The difference between the displacement of the intact oyster and the shell after removing the oyster meat was taken to be the volume of the shell's cavity. Dry meat weight was determined by drying the oyster meats in tared aluminum pans at 100°C until a constant weight (±0.01 g) was obtained.

RESULTS

Hydrographic Data

The greatest differences between surface and bottom values were 9 ppt for salinity, 2°C for temperature and 8.3 mg/m^3 for chlorophyll *a*. Surface and bottom salinities were within 1 ppt for ten of 20 months and chlorophyll *a* content was within 2 mg/m^3 for five of the 20 months (Table 1).

TABLE 1.

Temperature, salinity and Chlorophyll *a* content of water samples collected at monthly intervals from two depth.

	Temperature (°C)		Salinity (ppt)		Chlorophyll *a* (mg/M^3)	
	Top	Bottom	Top	Bottom	Top	Bottom
1973						
January	14.0	14.0	24.0	28.0	10.3	12.1
February	13.0	13.0	25.0	25.0	5.5	4.6
March	17.0	18.0	30.0	30.0	3.7	3.3
April	22.0	21.0	22.0	25.0	4.3	3.6
May	21.0	21.0	30.0	30.0	4.3	4.6
June	28.0	27.0	19.0	28.0	4.2	12.5
July	–	–	–	–	–	–
August	–	–	–	–	–	–
September	–	–	23.0	25.0	2.8	3.1
October	24.0	26.0	23.0	29.0	3.7	1.1
November	24.0	24.0	29.0	30.0	0.7	0.7
December	19.0	18.0	26.0	27.0	5.2	4.9
1974						
January	20.0	18.0	16.0	24.0	8.4	5.1
February	16.0	16.0	28.0	28.0	5.6	5.9
March	17.0	19.0	21.0	21.0	4.3	4.5
April	21.0	20.0	18.0	22.0	5.6	5.9
May	26.0	26.0	22.0	25.0	4.9	2.4
June	27.0	27.0	25.0	28.0	11.4	5.7
July	29.0	29.0	32.0	30.0	1.6	1.9
August	27.0	28.0	26.0	28.0	2.6	1.6
September	24.0	25.0	24.0	24.0	3.7	3.8
October	21.0	22.0	25.0	25.0	1.6	1.7

– indicates no samples were taken.

Seasonally, salinities varied from a low of 16 ppt (January 1974) to a high of 32 ppt (July 1974), temperatures varied from a low of 13°C (February 1973) to a high of 29°C (July 1974) and chlorophyll *a* content varied from almost none (0.7 mg/m^3, November 1973) to a high of 12.5 mg/m^3 (June 1973).

Growth and Survival

The growth patterns of oysters offshore were comparable at all five levels. Oysters at levels one and two were only slightly larger (1–3 mm) in mean length at termination than oysters held at other levels (3, 4 and 5) (Figure 3). The oysters increased in length from an initial size (estimated from sampling 60 of 600 oysters) of 68 mm to a final size (estimated from sampling surviving oysters) of 96 mm, representing a gain of 41% for oysters from the first and second level. The least growth occurred at the third level where oysters grew to a mean size of 93 mm, representing a length gain of 37%. Growth rates of oysters ranged from 1.2 mm per month (level 3) to 1.4 mm per month (levels 1 and 2) over the 20-month period. After four months, oysters were of a legal market size (76 mm). Initially only 33% of the oysters were of a legal size.

The oysters held at the first level increased in weight from an average of 85 g (for 120 oysters) to a final average

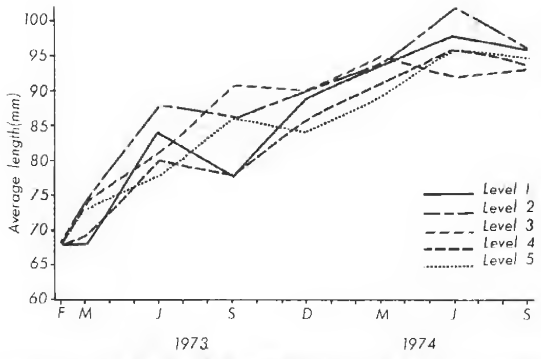

Figure 3. Growth of oysters in terms of average length in mm for 20 months. Initial length was based upon the average of 60 oysters. The values for June and September 1974 are based upon the average of 5 oysters, except level 4 for September 1974 based upon 2 oysters. All other values are based upon the average of 10 oysters.

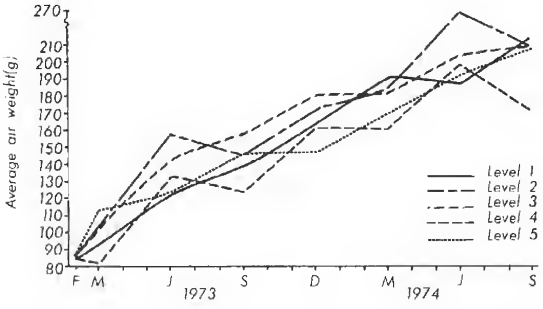

Figure 4. Growth of oysters in terms of average weight in g for 20 months. Initial weights were based upon average of 120 oysters. The values for June and September 1974 are based upon the average of 5 oysters except level 4 for September 1974 based upon 2 oysters. All other values are based upon the average of 10 oysters.

weight of 215 g (for 5 oysters), representing a gain in weight of 150% over the 20-month period (Figure 4). The five oysters sampled from each of the levels 2, 3 and 5 were of the same final average size (209 g), representing a gain of 139%. The two surviving oysters from the fourth level averaged 170 g.

Oysters were lost (due to bag failure) primarily from the two lower levels, while the greatest mortality occurred at the upper three levels (Figure 5). Ninety of the initial 600 oysters were known to have died during the 20 months of the study. Sampling removed 297 oysters from the study. An additional 145 oysters were missing from the bags, amounting to a total of 442 oysters either lost or eliminated from the study. The monthly mortality rate was used to estimate that eight deaths would have occurred in the 442 oysters had they been present throughout the study. The eight oysters considered to have died were added to the deaths actually recorded to obtain an adjusted number of deaths resulting in a total estimated mortality of 16%. Sixty percent of the total deaths occurred at the first two levels. Only 6% of the deaths were recorded from the fourth level. Seventeen percent of the total deaths occurred at both the third and fifth levels. The bottom two levels, however, accounted for 58% of all missing oysters, with level four accounting for 38% of all losses. For all levels, the greatest number of oysters lost (69) for a given month occurred during February 1974, amounting to 47% of all missing oysters.

Labyrinthomyxa marina Infection

Despite the attempt to secure disease-free oysters by collecting from a low-salinity area, incidence of the fungus parasite, *L. marina*, in oysters offshore was greater than for oysters at the collecting site (Figure 6). The Morgan Point Reef was sampled initially in November 1972 and the parasite was not found in 25 oysters assayed. Additional observations in December 1972 (22 oysters), May 1973 (25 oysters) and September 1973 (15 oysters) were also negative for the parasite. In October 1973, 3 of 24 oysters assayed showed a low level of infection (W.I., 0.1; I., 12%). Examination of

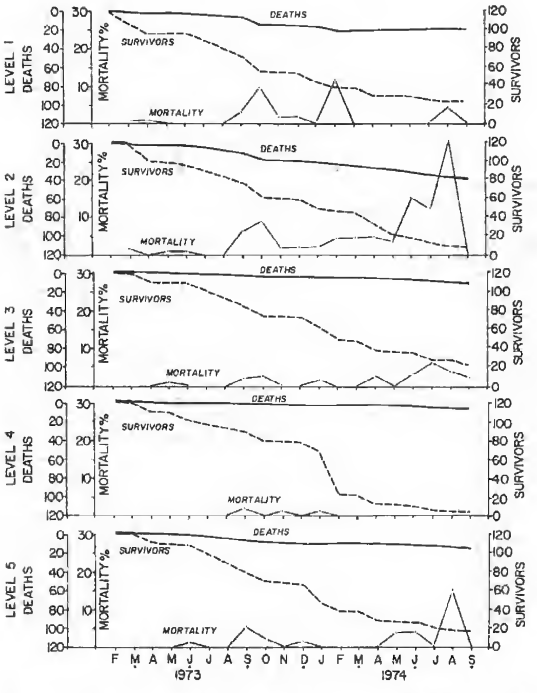

Figure 5. Number of survivors, adjusted number of deaths and monthly mortality. Months during which oysters were removed are noted by an asterisk. The area between the plots for deaths and survivors represents losses.

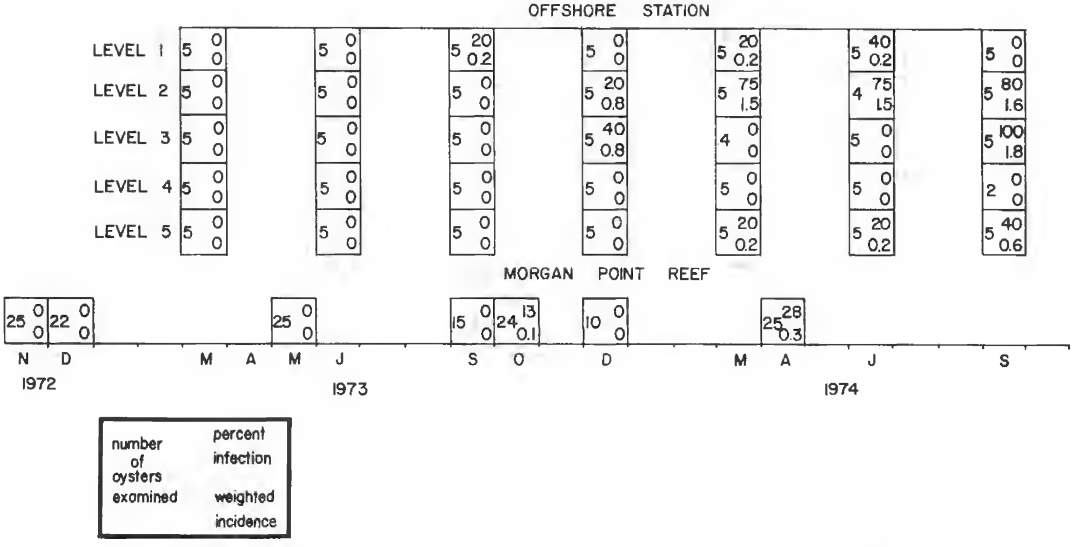

Figure 6. Incidence of infection by *Labyrinthomyxa marina* in oysters at two locations on the Texas coast.

10 oysters from the reef in December 1973 failed to detect the parasite and a final observation of 25 oysters in April 1974 revealed that the parasite was present at a higher level than previously detected (W.I., 0.3; I., 28%).

Oysters offshore remained free of the parasite until the seventh month (September 1973) when the fungus was detected in 1 out of 5 oysters assayed from the first level. By the tenth month (December 1973) the fungus was found in 1 out of 5 oysters from the second level, 2 out of 5 oysters from the third level and at 13 months (March 1974) in 1 out of 5 oysters from the fifth level. The fungus was not found in 32 oysters assayed at various times from the fourth level.

Condition Index

The seasonal pattern of condition index followed the same trends at each of the five levels (Figure 7). The value of 21 recorded for oysters from the first level for March 1973 is probably an error, as Butler (1949) reports that condition factors may range from 1 to 17 with 10 indicating a marketable oyster. Samples of ten oysters had their best condition index the first June (1973) after being placed offshore (14.8, 15.5, 14.7, 13.5, and 13.2 for levels 1 through 5, respectively). The condition index for samples of ten oysters declined in December 1973 (7, 5, 7, 5 and 5 for levels 1 through 5, respectively), improved slightly in March 1974 (9.3, 10.8, 10.4, 10.0 and 7.9 for levels 1 through 5, respectively), and then declined to the lowest values of the study in June 1974 (2.2, 2.1, 1.3, 1.4 and 1.5, respectively).

DISCUSSION

Growth of oysters in this study was not affected by the depth at which they were cultured, since growth was similar at the five arbitrary depths down to 8 meters. It is therefore considered biologically feasible to utilize the deeper water offshore from the Texas coast for suspension culture of oysters if techniques are developed to reduce losses from bag failures. The growth rate of 1.2 mm/month to 1.4 mm/month for oysters for this study was less than the growth rate of 5.1 mm/month to 8.1 mm/month reported by Gunter in 1951 for oysters found attached to templates off Texas and Louisiana. The report of Gunter (1951) represents growth from set to market size oysters while adult oysters (mean initial size 68 mm) were utilized in this study. Growth rates for comparable sized oysters as used in this study would be approximately 2 mm/month as predicted by Ingle and Dawson (1952). However, the growth rate of oysters (based upon length) will vary according to year and area. Hofstetter, Heffernan and King (1965) reported on tray studies from two reefs in Galveston Bay for two years (1963 and 1965). Growth of oysters in trays from Switchover Reef (an artificial reef) during eight months (May–December) was 3.7 mm/month during 1963 and 1.4 mm/month during 1965. Oysters from Hanna's Reef (a natural reef) grew 0.5 mm/month during 1963 and 1.9 mm/month during 1965. Growth of oysters offshore in this study is therefore considered consistent with that expected for comparable sized oysters from commercial reefs in Galveston Bay.

The seasonal pattern of condition exhibited by oysters from each of the five arbitrary depths was similar. This would be expected as Loosanoff and Engle (1942) noted that depths up to 30 feet did not affect the time of spawning (which influences seasonal condition) for oysters. In

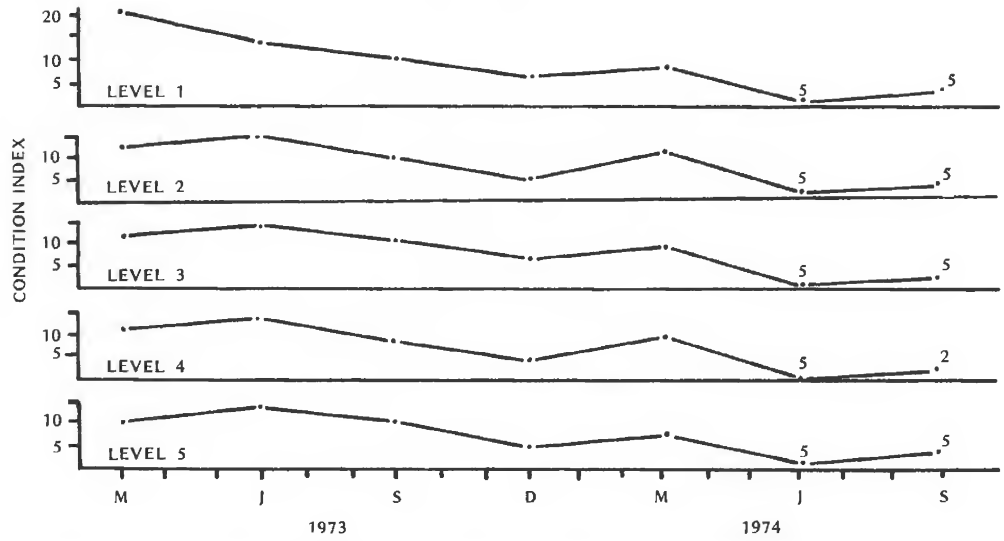

Figure 7. Average condition index of oysters. Each point represents the average of 10 oysters unless otherwise indicated by a number.

addition the amount of food available to the oysters in this study as evidenced by the chlorophyll *a* content of the water was similar for the surface and bottom water. However, the oysters were in best condition in June after being transferred offshore and in poorest condition in June of the following year. A lack of spawning due to their having been transferred would possibly account for the high condition during the first summer. Seasonally one would expect a low condition during the summer months as noted for the second summer.

There was no evidence of stratification of surface and bottom waters as indicated by hydrographic data. The hydrographic data suggest that the water was vertically uniform (to 10 meters) over most of the year. The oysters were probably in the same water mass as indicated by similarities in their growth and seasonal condition. There was no evidence of mortality associated with stratification as found by Kajikawa, Sano and Soguri (1953).

Both the flatworm *Stylochus* and the southern oyster drill *Thais haemastoma* were present in this study, but not in large numbers. The drills observed were all small and did not pose a problem to the large oysters. It is possible that the fungus *L. marina* was at least partially responsible for some of the mortality noted during this study. The fungus was more prevalent in the first three levels, corresponding to the greater number of deaths recorded from those levels (77% of total deaths). Increase in infection noted after October 1973 was possibly due to the spread of the fungus from diseased oysters placed on the platform at that time. The estimated total mortality of 16% for this study is less than the mortality expected on commercial beds where one bushel of oysters (300 oysters) is harvested for every bushel (2000 oysters) of seed oysters planted (McHugh and Andrews 1955). In Louisiana the "annual mortality rates of oysters more than a year old are usually in excess of 60% annually" (Mackin 1961).

Loss of oysters from torn bags was a major problem in this study. Bags were torn due to the constant wave action and strong currents and to growth of oysters whose sharp bills cut and abraded the mesh. Bags also tore due to pins catching on the grating during examination and on other bags when suspended. Some Vexar bags tore easily because of their faulty construction. The disappearance of a large number of oysters (47% of all oysters missing) during February 1974 from levels four and five was possibly due to some submerged object washing through the platform and knocking bags off, as entire bags were lost with bagging and pins swept clear of the chain and cable.

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Ultrastructure of Lymphocystis in the Heart of the Silver Perch, *Bairdiella chrysura* (Lacépède), Including Observations on Normal Heart Structure

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ULTRASTRUCTURE OF LYMPHOCYSTIS IN THE HEART OF THE SILVER PERCH, *BAIRDIELLA CHRYSURA* (LACÉPÈDE), INCLUDING OBSERVATIONS ON NORMAL HEART STRUCTURE

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ABSTRACT The fine structure of normal heart muscle from the silver perch, *Bairdiella chrysura* (Lacépède), is similar to that previously reported for marine and freshwater teleosts.

Cardiac lymphocystis is a viral disease manifested by single, giant-cell lesions variously located in the epicardium, trabecular spaces, and subendocardium—in direct apposition to myocardial cells. Occasionally, the hyaline capsule of lymphocystis cells partially surround myocardial cells but cause no pathological changes or inflammatory reaction.

The lymphocystis cells contain typical cellular organelles, including the viroplasmic net unique to these cells. Annulate lamellae, often continuous with the rough endoplasmic reticulum, are present, usually along the periphery of the cell. Some elements of the rough endoplasmic reticulum are dilated and contain a finely granular material, but others contain cross-banded fibrils, each having a periodicity of 30 nm. Similar fibrils are present in the perinuclear cisternae.

INTRODUCTION

Lymphocystis is a non-lethal, giant-cell, viral disease of marine and freshwater teleost fishes. The self-limiting disease is mainly manifested by temporary external tumorous cutaneous lesions. However, lesions have been reported in the eye (Huizinga and Cosgrove 1973, Smith 1973, Lawler et al. 1974, Dukes and Lawler 1975); gastro-intestinal tract, mesenteries and peritoneum (Woodcock 1904, Awerinzew 1909, Bangham and Hunter 1939, Nigrelli and Smith 1939. Smith 1973, Lawler et al. 1974, Russell 1974); ovaries (Woodcock 1904, Awerinzew 1909, Nigrelli and Smith 1939); spleen (Nigrelli and Smith 1939, Huizinga and Cosgrove 1973, Lawler et al. 1974, Russell 1974); liver, gall bladder, kidneys and testes (Lawler et al. 1974, Russell 1974); muscle (Russell 1974); and in the heart (Bangham and Hunter 1939, Lawler et al. 1974).

Lawler et al. (1974) previously reported on the incidence of external and internal lymphocystis infections in silver perch collected from Mississippi Sound. The morphology of cardiac lymphocystis lesions has been given little attention; thus, we have expanded our previous study to include microscopic examination of these lesions in silver perch. Our observations on the ultrastructure of both normal heart and cardiac lymphocystis form the basis of this report.

MATERIALS AND METHODS

Sixty-two silver perch, *Bairdiella chrysura* (Lacépède), out of 923 collected in 1972 and 1973 from the estuarine waters of Mississippi Sound (30°23′29″N, 88°47′50″W) exhibited extensive external and/or internal lymphocystis, including five with cardiac lesions (Table 1). Another specimen (M-644) spontaneously developed lymphocystis while retained in an aquarium from May 25 to July 9, 1973, in salinities ranging from 2.8 to 5.6 ppt. It also had extensive external and internal lesions, including cardiac lesions.

Of the six fish, four had an isopod, *Lironeca ovalis* (Say), attached to their gills and another showed evidence of previous infestation. Host data for all silver perch used in this study are summarized in Table 1.

Normal and lymphocystis-infected hearts were prepared for gross and electron microscopic observations in the manner previously described (Lawler et al. 1974). In addition, cardiac tissue was embedded in paraffin and sectioned for staining with hematoxylin and eosin, periodic acid Schiff's (PAS) reaction, Alcian blue, and Masson's method for connective tissue.

The hearts from silver perch M-532 and M-644 were initially fixed in 10% buffered formalin. Tissue was excised and prepared for electron microscopy as if fresh.

Selected heart tissue was flooded with cold 3% glutaraldehyde, minced with a razor blade, and then placed in a larger volume of cold glutaraldehyde for 24 hours. The tissue was then washed in two changes of 0.1M phosphate buffer for 2 hours, post-fixed in cold 1% osmium tetroxide for 2 hours, and dehydrated in a graded series of ethanol over a 1-hour period.

The tissue was embedded in a Maraglas-Cardolite mixture according to the procedures of Freeman and Spurlock (1962). Ultrathin sections were cut with an LKB Ultrotome and doubly stained with uranyl acetate and lead citrate. Sections were examined and photographed using a Siemens 1A Elmiskop electron microscope.

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TABLE 1.

Host data for silver perch exhibiting cardiac lymphocystis

Features Observed	Host Number					
	M-530	M-532	M-535	M-628	M-632	M-644
TL[1] Host (mm)	100	104	97	122	138	44
Date Collected	10/6/72	10/11/72	10/14/72	5/29/73	5/30/73	5/25/73 (7/9/73)[2]
Type of Lymphocystis Infection	Natural	Natural	Natural	Natural	Natural	Spontaneous[3]
Isopod Present	L Gills	R Gills	R Gills (previously)	R Gills	L Gills	None
External Lymphocystis						
Head	–	+	+	+	–	+
Nostril	L, R	L, R	L, R		–	L, R
Eye (surface)	–	–	R	L	–	R
Jaw	–	–	Lo	–	–	Lo
Mouth	–	–	–	Ro	–	Ro
Operculum	L	L, R	R	R	–	L, R
Gill	L, R	L, R	L, R	L, R	–	L, R
Pseudobranch	L, R	L, R	L, R	–	–	L, R
Isthmus	+	+	–	+	–	+
Body surface	–	R	L, R	L, R	–	L, R
Dorsal fin	B	B	B	B	–	B
Pectoral fin	L, R	–	L, R	L, R	–	L, R
Pelvic fin	L, R	L	L, R	L, R	–	L, R
Anal fin	+	+	+	+	–	+
Caudal fin	–	+	+	–	–	+
Internal Lymphocystis						
Heart	+	+	+	+	+	+
Behind eye	L, R	–	L, R	L, R	–	–
Kidney	L, R	–	L, R	–	–	–
Mesenteries	+	+	+	–	–	+
Spleen	+	+	+	+	–	+
Liver	+	–	+	–	–	+
Ovary	+	–	–	–	?	–

[1]TL = total length
[2]Specimen held in aquarium from date collected and removed on this date
[3]Infection appeared in aquarium

Lo = Lower
Ro = Roof
L = Left
R = Right
B = Both

RESULTS

Normal Heart

The walls of the atrium and ventricle generally consist of the epicardium, the myocardium and the endocardium. The myocardium is fairly thick in the ventricle but thin in the atrium, often no thicker than the diameter of a single muscle cell. In some areas, especially in the atrium, there are gaps where the myocardium is absent; thus at those sites the wall consists of epicardium, collagen bundles, and endocardium. The surfaces of the epicardial, myocardial, and endocardial cells are strongly PAS positive and alcianophilic at pH 2.5 and 1.0

Epicardium. The epicardium consists of a single uninterrupted layer of epithelial cells underlain by bundles of collagen fibers (Figure 1). The epicardial cells are flattened and each contains a single oval nucleus. The cells form finger-like cytoplasmic processes which interdigitate with or overlap similar processes of adjacent cells with which they are linked by desmosomes.

Myocardium. The atrial myocardium is thin and the branching muscular trabeculae are loosely arranged, whereas the ventricular myocardium is thicker and the trabeculae are more compact. Myocardial cells throughout the two chambers are structurally similar and contain all the organelles usually present in cardiac muscle cells (Figures 2, 3). Each cell contains a central nucleus, and the myofibrils exhibit A, I, and Z bands. The myofibrils tend to be located at the cell periphery and exhibit the pattern of six thin filaments to one thick filament that is typical for vertebrate myocardial cells. The myocardial cells in the atrium, as well as some in the ventricle, contain numerous specific granules.

A transverse tubular system is not present in the myocardial cells but a sarcoplasmic reticulum (SR) is sparsely

scattered throughout, particularly between myofibrils and often in close association with the cell membrane where it forms subsarcolemmal cisternae.

The mitochondria are predominantly located in the cell core but are also scattered between myofibrils. They are often pleomorphic and contain flattened cristae.

The myocardial cells are joined end-to-end by intercalated discs, the gaps of which occasionally contain membranous profiles and osmiophilic granules resembling glycogen (Figure 3). These components are perhaps artifacts of tissue preparation. An occasional macula adherens is encountered in the disc.

Endocardium. The endocardium lines both heart chambers and consists of an uninterrupted layer of endocardial cells underlain by large bundles of collagen fibers (Figures 1, 2). The endocardial cells are larger in the atrium where they protrude into the heart chamber. In both chambers these cells are packed with an elaborate smooth endoplasmic reticulum (SER) and contain numerous residual bodies, which are evidently lipofuscin (Howse and Welford 1972).

Cardiac Pathology

Lesions consisting of aggregations of lymphocystis cells, common in external manifestations, are not present in the heart. The distribution of the lymphocystis cells in each heart is given in Table 2. Many of the cells are each surrounded by an outer cellular envelope consisting of several layers of epithelioid cells (Figures 4–6, 8, 9).

Cellular Envelope. The cellular envelope is composed of uninucleate cells connected by desmosomes. The cells contain the usual organelles; however, adjacent cells frequently vary in the amount of smooth and rough endoplasmic reticulum present. Some cells possess a prominent SER, whereas others exhibit an elaborate rough endoplasmic reticulum (RER) (Figure 9). Some cells differ also in having pigment granules, lipofuscin, and fibrillar material in the perinuclear region. These cells are evidently fibroblasts.

Lymphocystis Lesions. Individual lymphocystis cells are variously encountered in the epicardium (Figure 4), the trabecular spaces (Figure 5), and subendocardium—in direct apposition to the myocardial cells (Figure 6). They contain numerous virions scattered throughout the cytoplasm among the usual cellular organelles, including viroplasmic nets unique to these cells (Figures 6, 7). The fine structure of the viroplasm is similar to that of nuclear chromatin except that a delimiting membrane is not present.

Mitochondria are numerous and varied in size and shape. Their cristae are sparse. Smooth endoplasmic reticulum is abundant in some cells, especially in the cortical cytoplasm, but is poorly defined in others.

The RER is elaborate, especially along the cell periphery (Figure 8). Frequently, the RER is markedly dilated and contains a fine granular material of electron density similar to that of the hyaline capsule, but other regions of the RER contain numerous cross-banded fibrils (Figures 8, 12, 13). These bands exhibit a periodicity of about 30 nm. Occasionally, these fibrils extend into the granular material contained in the dilated RER (Figure 13). Cross-banded fibrils are also occasionally present in the perinuclear cisterna (Figure 12).

Annulate lamellae are present in the peripheral cytoplasm and consist of parallel RER cisternae exhibiting pore-annuli in register with each other (Figures 14–16). The intercisternal regions are from 80 to 110 nm wide and contain osmiophilic granular material. These lamellae are occasionally continuous with membranes of the RER (Figures 14, 15).

The lymphocystis cell surface is marked by numerous deep invaginations filled with hyaline (Figures 8, 10). The hyaline capsule gives the usual reactions of mucopolysaccharides to the histochemical stains employed in this study. They are PAS and Alcian blue positive, and are light blue following Masson's procedure for connective tissues. The capsules consist of an amorphous matrix in which numerous fine fibrils are embedded (Figures 8–10).

Occasionally, the hyaline capsule at least partially engulfs a myocardial cell (Figure 10), but this close relationship causes no histopathological changes in the muscle cell. No unusual structural changes are evident in the myocardial cells nor are inflammatory cells present in the immediate intercellular spaces. These spaces occasionally contain a finely granular material.

Virions are rarely present in the interstices (Figure 11). The radial-fibrillar region that typically surrounds intra-

TABLE 2.

Number and location of cardiac lymphocystis cells (LC) in four silver perch. The numbers enclosed in parentheses represent the numbers encased in a cellular envelope.

Specimen	Total LC	Atrial Endocardium	Atrial Epicardium	Ventricular Endocardium	Ventricular Epicardium
M-632	8 (8)	0	4 (4)	4 (4)	0
M-532	30 (11)	5 (1)	1 (1)	15	9 (9)
M-530	3 (2)	1 (1)	1 (1)	1	0
M-535	8 (6)	1	1 (1)	4 (2)	3 (3)

cellular virions is also present but denser about the interstitial virions.

Frequently, hyaline extensions of the capsule weave tortuous courses among the cells of the envelope (Figures 4–6). The fine structure of the extensions is similar to that of the hyaline capsule except that some of the extensions contain collagen fibers. These fibers have a periodicity of about 70 nm and are particularly evident in hyaline extensions when viewed longitudinally.

DISCUSSION

The fine structure of the normal silver perch heart is similar to that described for other marine and freshwater fish species. However, the available information is sparse and fragmentary, except for a detailed account of the heart of the freshwater teleost, *Oryzias latipes* (Schlegel), by Lemanski et al. (1975) which presents an excellent discussion of the normal heart structure in a fish.

Although the present study dealt mainly with cardiac lymphocystis, internal lesions were present throughout the several organ systems of the perch. Our findings, together with those previously cited, suggest that internal lymphocystis infections are not as rare as previously believed (Walker 1957). The wide-spread occurrence of lymphocystis in the organ systems of perch supports the suggestion that internal lymphocystis may develop *in situ* rather than represent "displaced elements" (Nigrelli and Ruggieri 1965).

Lymphocystis appears to have a systemic phase as well as a localized external response phase. Over 30 years ago, Weissenberg (1945) suggested that the virus can gain entrance into the host vascular system via the gills. More recently, Smith (1973) and Dukes and Lawler (1975) observed lymphocystis in certain ocular tissues which seems to preclude all but a hematogenous mode of infection. The present rare finding of viral particles free in the interstitial space of the myocardium of perch further supports this view.

Of particular interest in this study are the findings of annulate lamellae located in the peripheral cytoplasm, and the fibril-containing RER and perinuclear cisternae in the lymphocystis cells. Annulate lamellae have been observed in the cytoplasm of a variety of metabolically active cell types. They are present in male and female germ cells of certain invertebrates and vertebrates, embryonic and adult somatic cells, and frequently occur in tumor and cancer cells (see reviews by Kessel 1968, Wischnitzer 1970). Although the function of annulate lamellae remains obscure, the bulk of the evidence suggests that they are involved in protein synthesis (Wischnitzer 1970). The peripheral location of the annulate lamellae and their structural continuity with the RER in lymphocystis cells suggests a role in both the synthesis of the fibrils present in the RER and perinuclear cisternae and the synthesis of the proteinaceous component of the hyaline capsule which is known to be rich in acid mucopolysaccharides (Pritchard and Malsberger 1968, Howse and Christmas 1970).

During the course of accelerated metabolism and rapid hypertrophy of the infected cell, fibrils or their precursor macromolecules are evidently extruded by the cell and become embedded in the hyaline component of the capsule. However, the aggregation of these precursor macromolecules within the cisternae may provide the close association necessary to promote interactions between them that leads to the synthesis of cross-banded fibrils. Since no cross-banded fibrils having a periodicity of 30 nm were encountered in the capsule their presence in the RER and perinuclear cisternae may reflect the loss of the capability of these organelles to expel their products. This may result from an accelerated protein synthesis that overloads the extrusion capacity of these organelles, or the lymphocystis cell may have reached the point of incompatibility between further growth and the available supply of metabolic nutrients; thus, the result is stasis, cell degeneration, and necrosis.

ACKNOWLEDGMENTS

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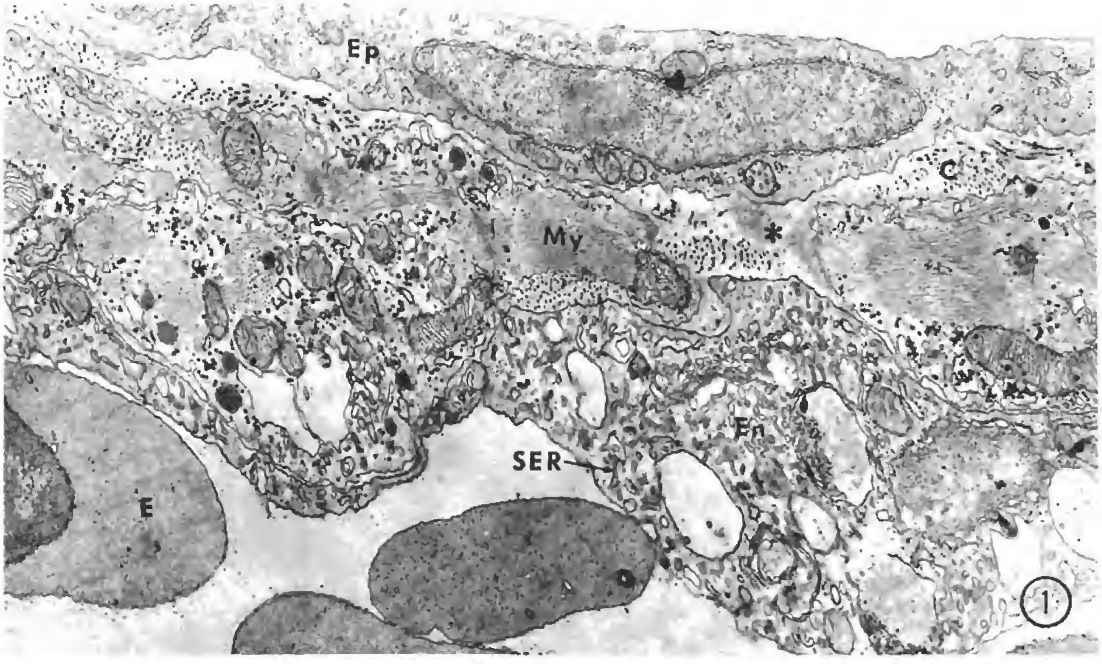
PLATE 1

EXPLANATION OF FIGURES

1. Electron micrograph of the normal atrial wall showing the epicardium (Ep), myocardium (My), and endocardium (En). Note gap (*) in the myocardium. C, collagen; E, erythrocyte; SER, smooth endoplasmic reticulum. X 26,700.

2. Electron micrograph of normal ventricular trabeculae showing the myofibrils in transverse and oblique views. En, endocardium; VHC, ventricular heart chamber; L, lipid droplet; M, mitochondria; N, nucleus. X 9,500


Ep
My
C
En
SER
E
1

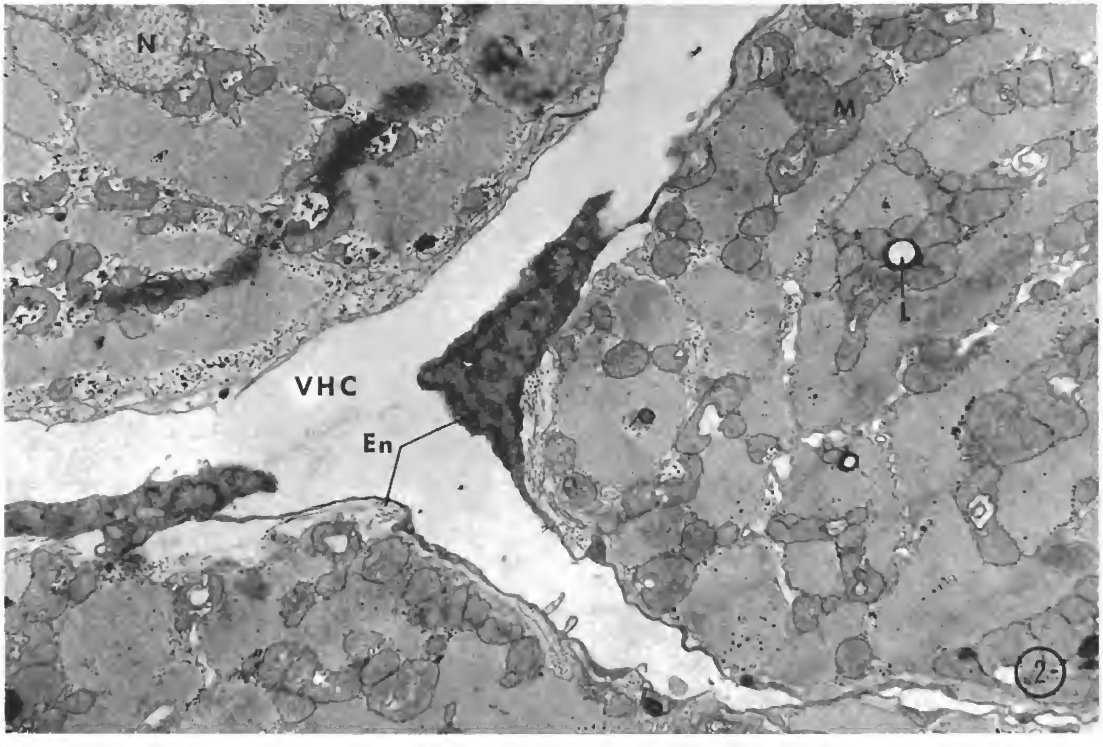

N
M
L
VHC
En
2

PLATE 2

EXPLANATION OF FIGURE

3. Normal myocardial cells sectioned longitudinally in the region of an intercalated disc (ID). G, glycogen; M, mitochondria; SR, sarcoplasmic reticulum; Z, Z bands. X 35,900. Inset: Section through an intercalated disc showing membranous profiles (arrows) in the gap. X 31,900.

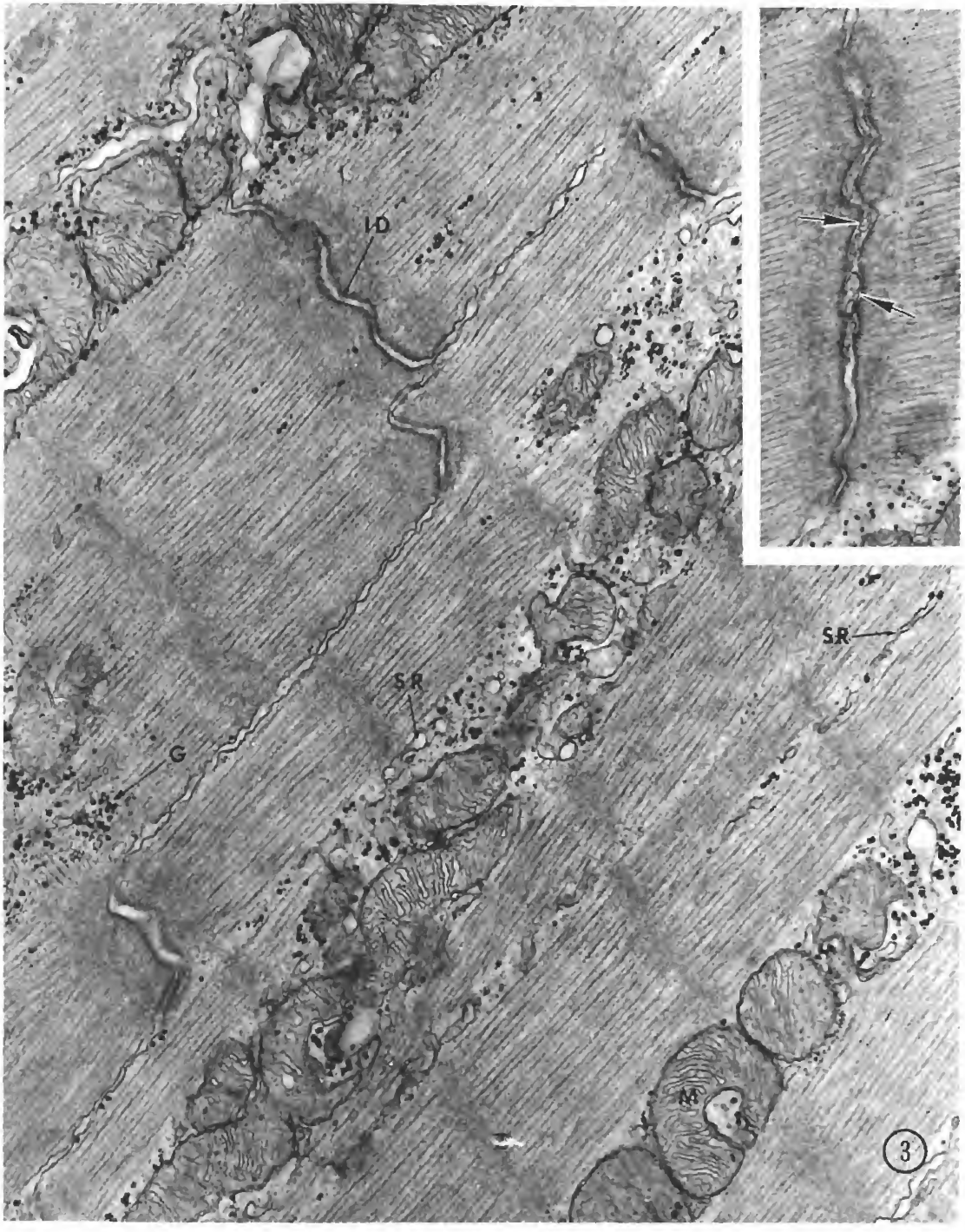

I-D
S.R
G
S.R
M
3

PLATE 3

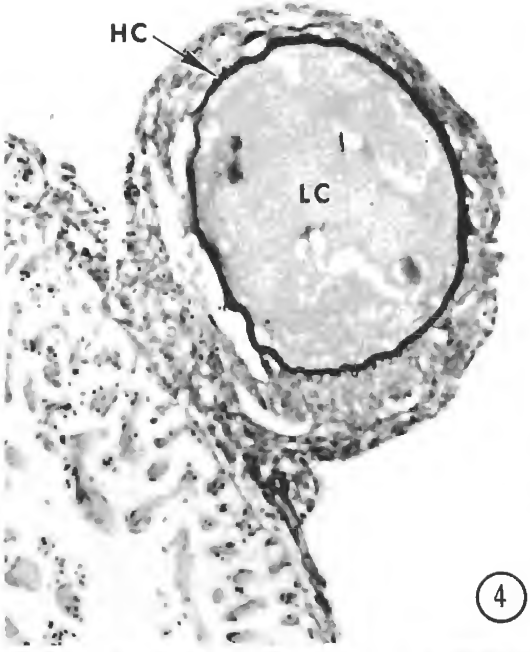
EXPLANATION OF FIGURES

4. Histological section showing a lymphocystis cell (LC) encapsulated in a cellular envelope attached to the atrial epicardium. Note darkly stained hyaline capsule (HC). Stained with PAS. X 330.

5. Histological section through a lymphocystis cell (LC) in the ventricle. Note the extension (arrows) emanating from the hyaline capsule and extending into the partial cellular capsule. Stained with PAS. X 350.

6. Light micrograph of a lymphocystis cell (LC) in plastic-embedded ventricle prepared for electron microscopy. The patches (arrow) present in the LC are large aggregations of virions. H, hemocytes; My, myocardium; CE, capsular extension. Stained with toluidine blue. X 1,170.

7. Electron micrograph of a section through one of the patches shown in Figure 6. Note the delicate radial-fibrillar region (arrows) that surrounds each virion (compare with Figure 11). The uniform spacing of closely-packed virions evidently is controlled by the radial-fibrillar region as concluded by Walker (1962) and Walker and Weissenberg (1965). X 50,500.


HC
LC
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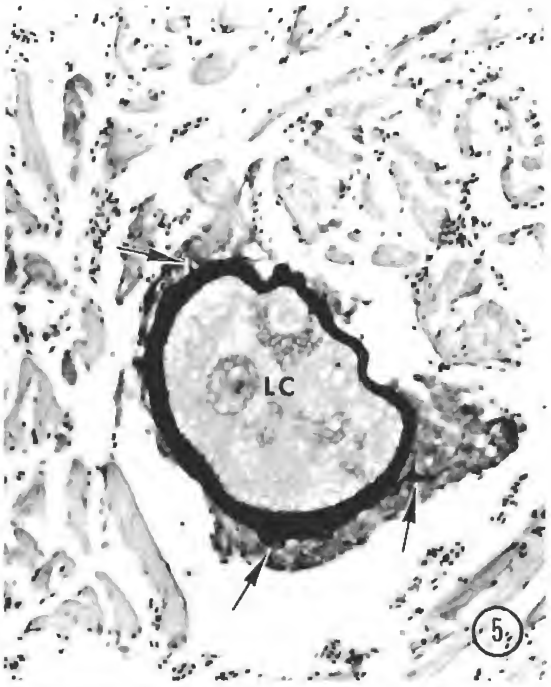
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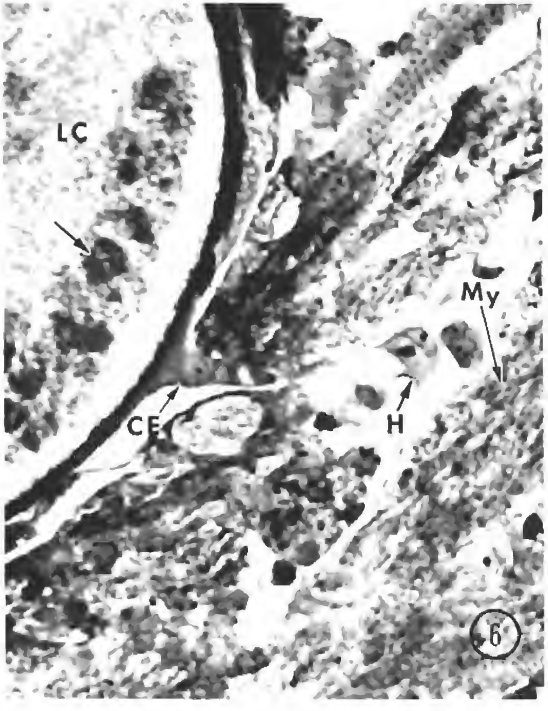
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My
CE
H
6

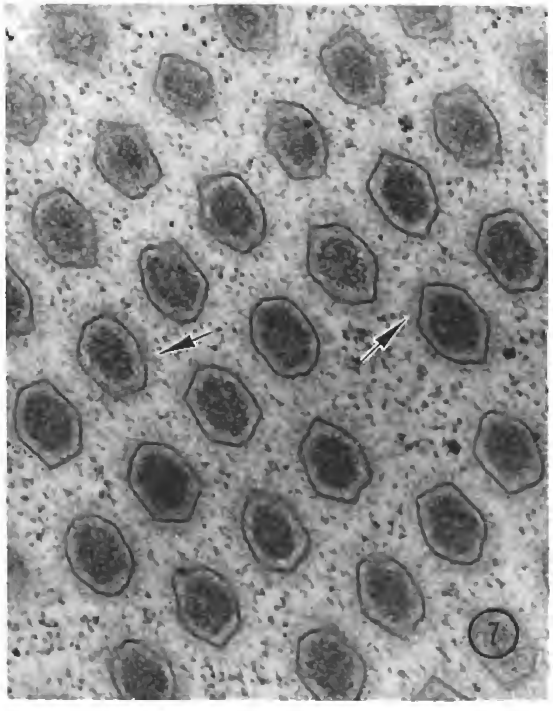
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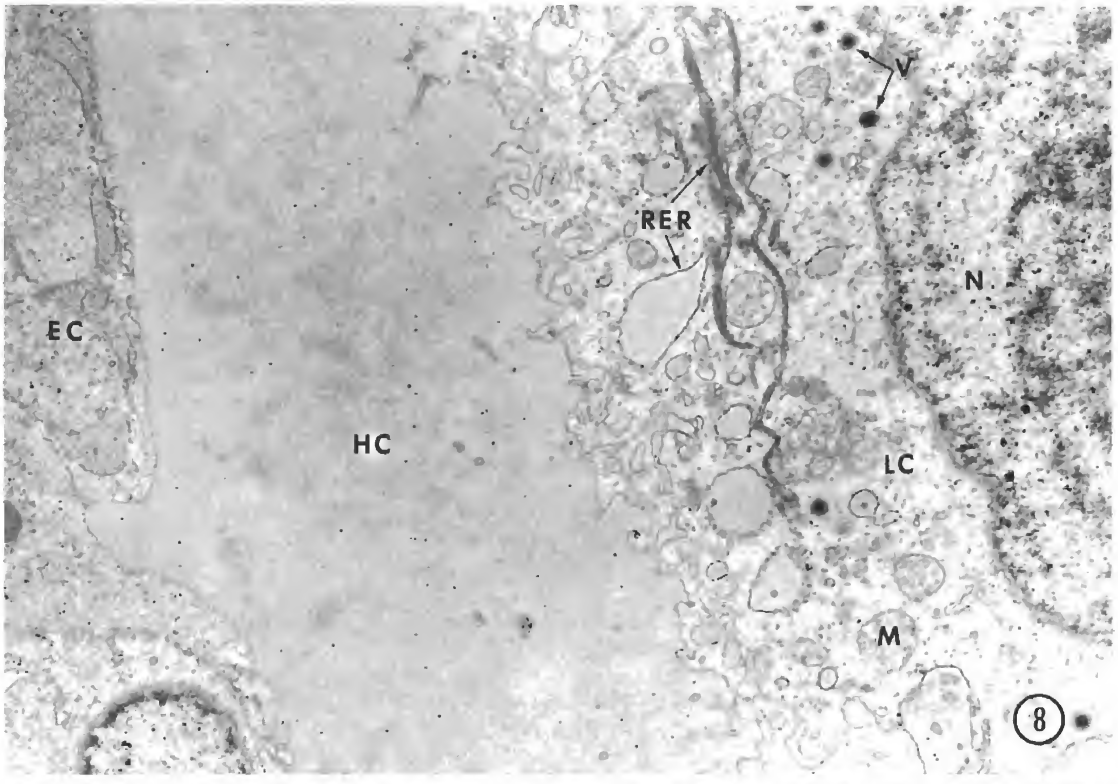
PLATE 4

EXPLANATION OF FIGURES

8. Section through the ventricle showing the hyaline capsule (HC) of a lymphocystis cell (LC) in contact with cells (EC) of the encapsulating envelope. M, mitochondria; N, nucleus; RER, rough endoplasmic reticulum; V, virus. X 12,500.

9. Electron micrograph of capsular extension (CE) which almost encircles a cell of the encapsulating envelope. Note fibrils (arrows) in the perinuclear region of the cell. HC, hyaline capsule; RER, rough endoplasmic reticulum. X 26,300.


V
RER
N
EC
HC
LC
M
8

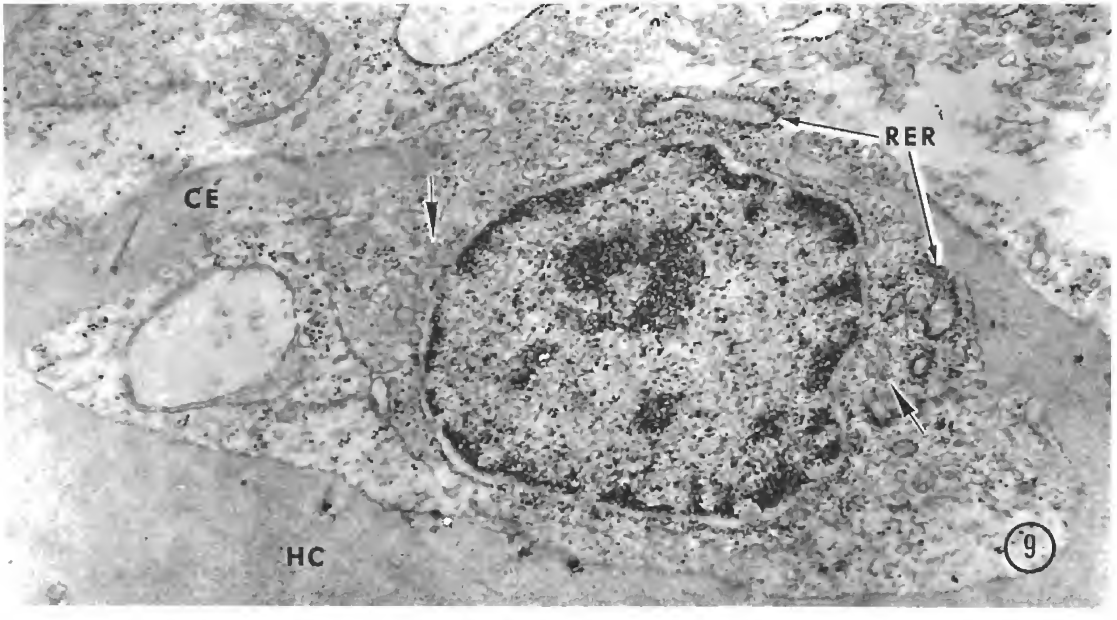
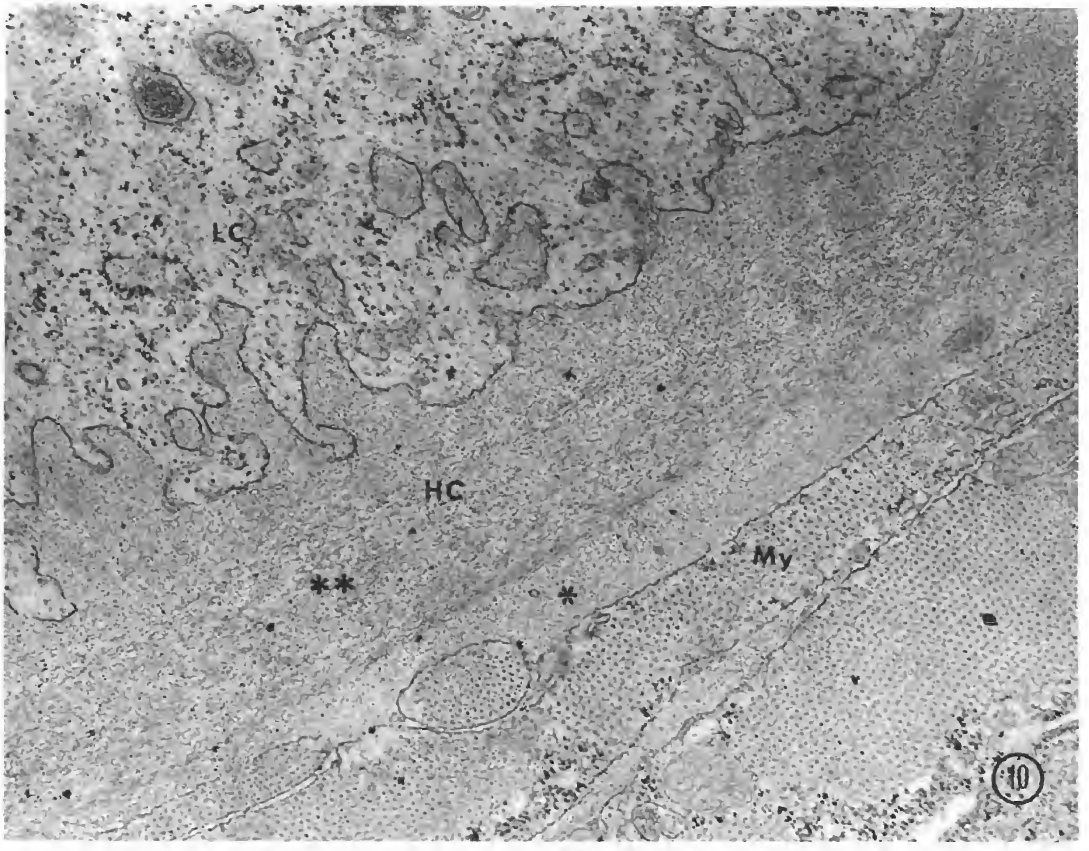

RER
CE
HC
9

PLATE 5

EXPLANATION OF FIGURES

10. Section showing the irregular periphery of a lymphocystis cell (LC), the hyaline capsule (HC) and cells of the ventricular myocardium (My) to which the capsule is apposed. Note that the capsule is divided into a thick inner (**) and a thin outer (*) layer by the orientation of its component fibrils. X 38,900.

11. Section through the ventricular myocardium showing a single virus particle (arrow) in the intercellular space. The particle is surrounded by a granular substance. X 44,000.


LC
HC
My
**
*
10

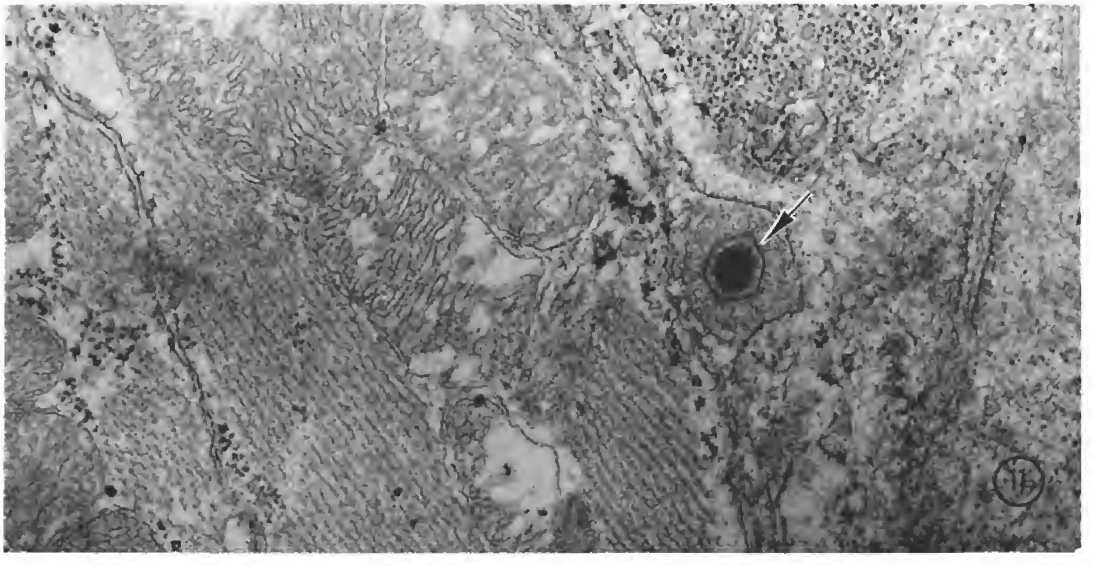

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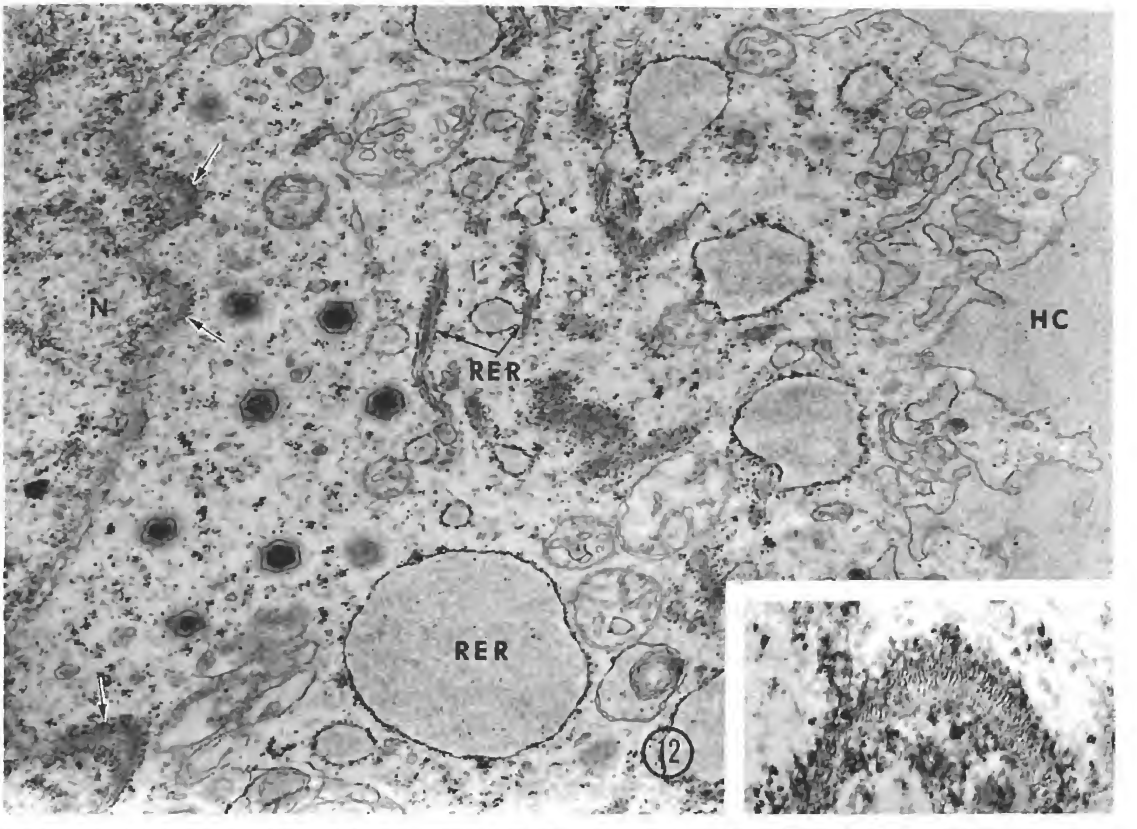
PLATE 6

EXPLANATION OF FIGURES

12. Electron micrograph of a lymphocystis cell. Some elements of the rough endoplasmic reticulum (RER) are markedly dilated and others contain cross-banded fibrils. Note fibrils present in the perinuclear cisterna (arrows). N, nucleus; HC, hyaline capsule. X 23,300. Inset: Higher power view of fibrils in the perinuclear cisterna. X 70,400.

13. Electron micrograph showing apparently active elements of the rough endoplasmic reticulum (RER). Note the fibril (arrow) extending into the granular substance of the dilated element. M, mitochondria. X 26,700.


N
RER
HC
RER
12

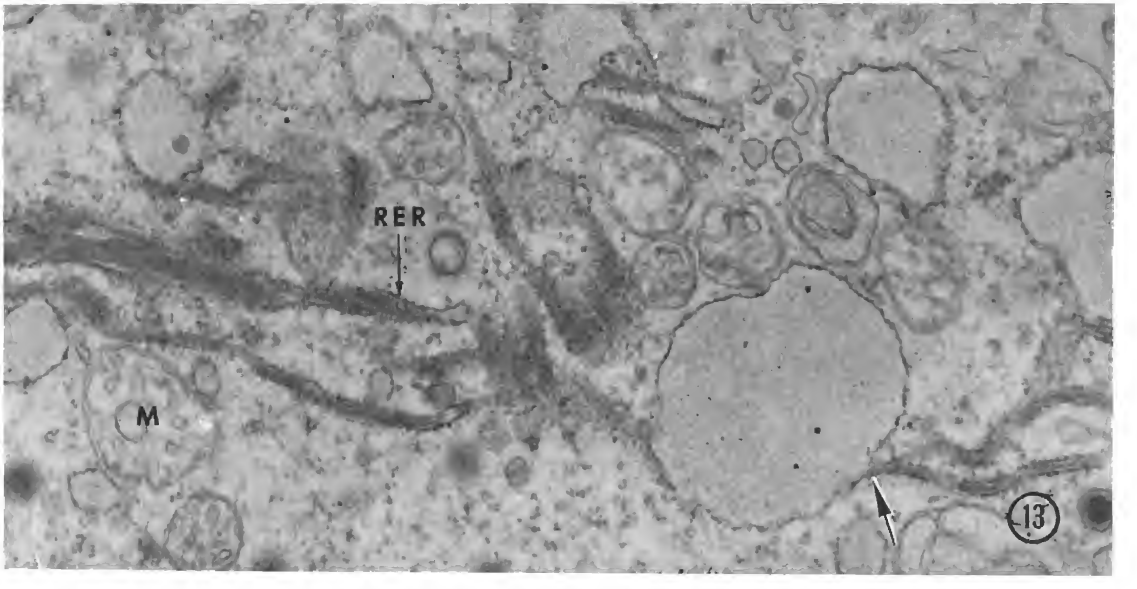

RER
M
13

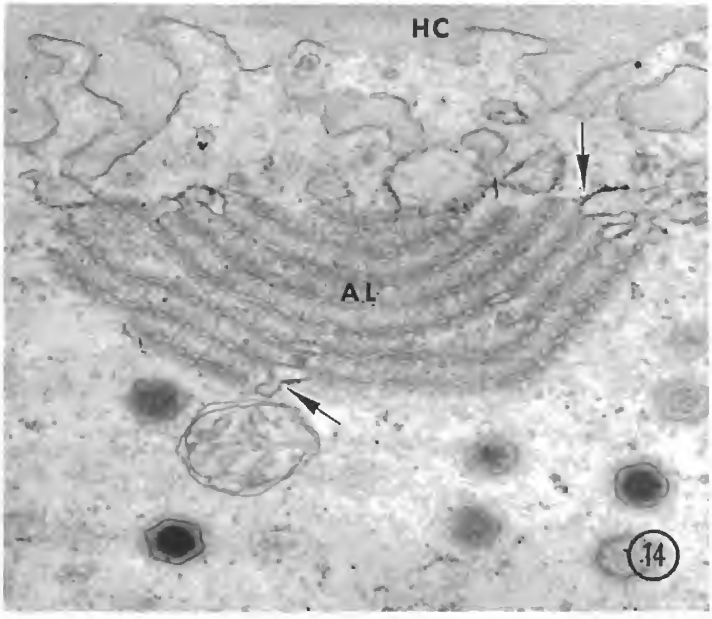
PLATE 7

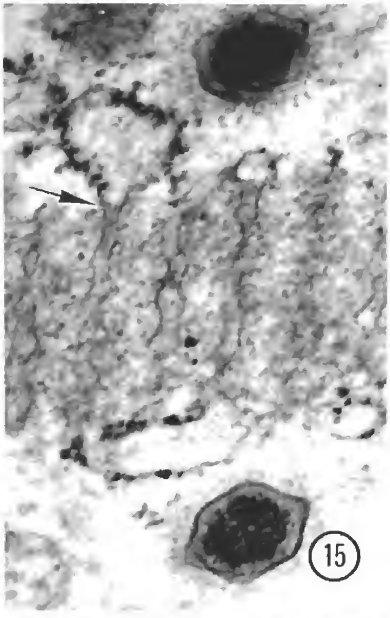
EXPLANATION OF FIGURES

14. Section through the periphery of a lymphocystis cell showing annulate lamellae (AL). Note continuity of AL with the RER (arrows). HC, hyaline capsule. X 35,200.

15. Higher power electron micrograph showing continuity of annulate lamellae with RER (arrow). X 80,500.

16. Annulate lamellae (AL) adjacent to cisternae of rough endoplasmic reticulum (RER) that contain cross-banded fibrils. X 80,400.


HC
AL
14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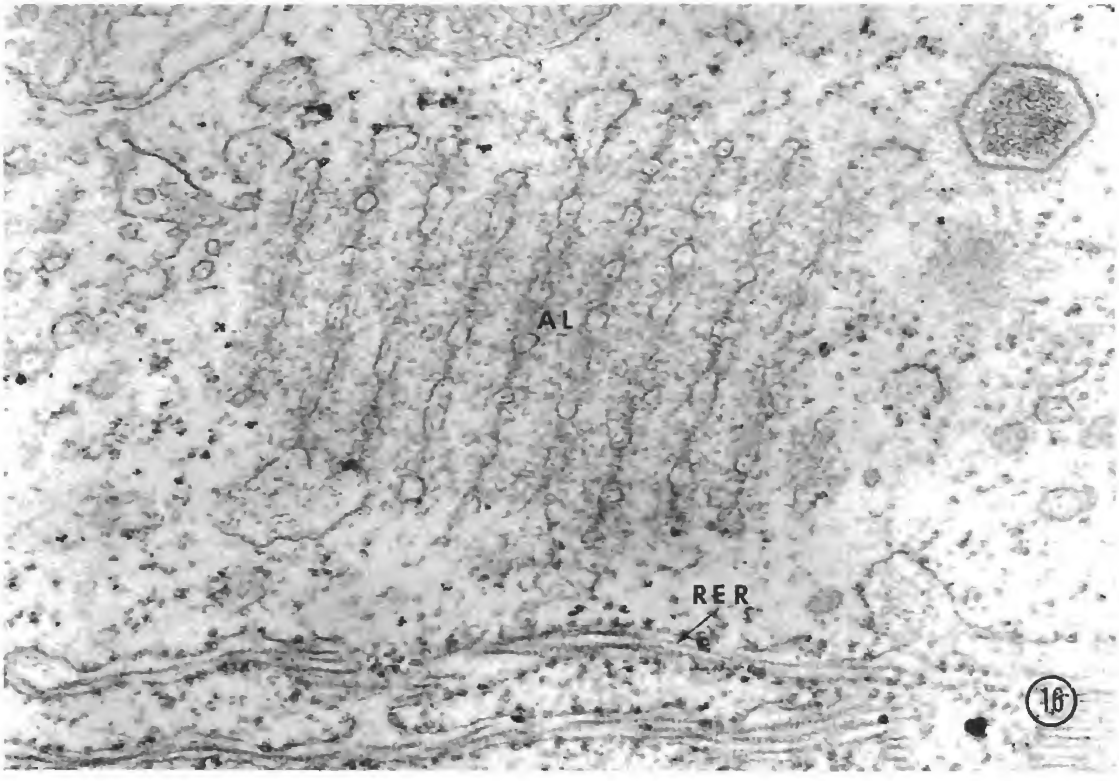
AL
RER
16

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A Selected Bibliography on the Mass Propagation of Rotifers with Emphasis on the Biology and Culture of *Brachionus plicatilis*

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A SELECTED BIBLIOGRAPHY ON THE MASS PROPAGATION OF ROTIFERS WITH EMPHASIS ON THE BIOLOGY AND CULTURE OF *BRACHIONUS PLICATILIS*

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ABSTRACT The rotifer *Brachionus plicatilis* has shown great promise as food for artificially reared fish and crustacean larvae. A list of references on mass propagation of rotifers is presented alphabetically by author. Citations cover and are indexed as culture, diet, ecology, physiology, population dynamics, reproduction, systematics, geographical distribution, food, and biology of rotifers with emphasis on *Brachionus plicatilis*.

INTRODUCTION

There has been a growing demand in recent years for food-organisms for artificially propagated fish and crustacean larvae. The brine shrimp, *Artemia salina*, is a widely used organism to feed larval forms. However, increasing costs of brine shrimp cysts have forced the aquaculturist to seek alternate sources of living food-organisms.

Some rotifers appear to fill this need in addition to providing other benefits. The rotifer *Brachionus plicatilis* is especially notable because of its short life cycle, simple dietary requirements, capability of high density cultivation, and nutrient value, and it has shown great promise as initial and supplementary food for larval fishes and crustaceans.

The following list of references, arranged in alphabetical order by author, is incomplete, but provides an easy reference to the pertinent literature. Citations cover and are indexed as culture, diet, ecology, physiology, population dynamics, reproduction, systematics, geographical distribution, food, and biology of rotifers with emphasis on the genus *Brachionus*. The term "diet" refers to food utilized by rotifers, whereas "food" denotes usage of rotifers by other organisms for food.

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SUBJECT INDEX

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Notes on Sarcophagids from the New Host *Romalea microptera*, and from *Terrapene carolina carolina*

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SHORT COMMUNICATIONS

NOTES ON SARCOPHAGIDS FROM THE NEW HOST *ROMALEA MICROPTERA*, AND FROM *TERRAPENE CAROLINA CAROLINA*

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ABSTRACT Sarcophagid fly larvae are reported from the new host *Romalea microptera* (Palisot de Beauvois), a lubber grasshopper. A new locality record is given for *Cistudinomyia cistudinis* (Aldrich).

Sarcophagid fly larvae parasitize a wide range of invertebrates and vertebrates (Aldrich 1916; Greene 1925; James 1947; Zumpt 1965). The sarcophagids reported herein were recovered from *Romalea microptera* (Palisot de Beauvois), a lubber grasshopper, and *Terrapene carolina carolina* (Linnaeus), the eastern or common box turtle.

One third-instar (8.5 mm long) larval sarcophagid was recovered from the hemocoel of a *Romalea microptera* collected on the Gulf Coast Research Laboratory grounds on 18 November 1971. Four puparia (8.0, 8.5, 9.0, 9.5 mm long) were found in the hemocoel of another *R. microptera* from lab grounds on 5 September 1974. It is not known if the puparia represent the same species as the larva as larvae must be reared to adults to ensure correct specific identification. Two of fourteen (14%) grasshoppers examined were infected (Table 1), both hosts being females. All sarcophagids plus one example of the host were deposited in the U. S. National Museum.

The third instar proved to be quite hardy; it remained alive in 70% ethanol for 20 minutes, then in AFA for about one hour, finally being killed by hot AFA. The four puparia appeared to be alive when removed, and were held on moist filter paper from 5–17 September in order to see if they would hatch. As they did not hatch, they were preserved.

Aldrich (1916) and Greene (1925) listed several sarcophagids that occur in grasshoppers; however, a review of the literature revealed no prior listing of *R. microptera* as a host. Also, Richard H. Foote (personal communication) noted that the USDA had ". . .no records of any sarcophagids from *Romalea*."

A sarcophagid was removed from a large lesion on the left rear leg of an eastern box turtle (*Terrapene carolina carolina*) collected near Gloucester Point, Virginia, by Kenneth W. Able on 16 September 1970. The larva was killed in boiling water, preserved in ethanol, and sent to W. W. Becklund, who identified it as *Cistudinomyia cistudinis* (Aldrich). It is deposited under USDA Par. Coll. 66098.

Aldrich (1916) noted that Packard (1882), Wheeler (1890), Emerton (1904), and Kepner (1912) had reported unidentified sarcophagid larvae from box turtles. True (1884) also reported an unidentified sarcophagid from a turtle. Verified reports of *C. cistudinis* are listed in Table 2. Further information on this species was presented by Knipling (1937).

Appreciation is expressed to Richard H. Foote, Chief, Systematic Entomology Laboratory, USDA; R. J. Gagne, A. B. Gurney, and Reece I. Sailer, Entomology Research Division, USDA; and to the late W. W. Becklund, Veterinary Sciences Research Division, USDA.

TABLE 1.

Romalea microptera examined for sarcophagids at Ocean Springs, Mississippi.

Date Collected	Body Length (mm)	Sex	No. Sarcophagids
18 Nov 1971	64	F	1
29 Nov 1971	58	F	0
10 Jul 1974	58	F	0
5 Sep 1974	58	F	4
13 Sep 1974	63	F	0
13 Sep 1974	45	M	0
16 Sep 1974	56	F	0
17 Sep 1975	58	F	0
25 Sep 1975	45	M	0
17 Oct 1975	44	M	0
17 Oct 1975	48	M	0
21 Sep 1976	60	F	0
5 Oct 1976	64	F	0
6 Oct 1976	62	F	0

TABLE 2.

Reports of *Cistudinomyia cistudinis* (Aldrich).

Host	State	Author
Chrysemys picta	New Jersey	Chidester (1915)
Box turtle	New Jersey	Aldrich (1916)
Terrapene carolina	New Jersey	Greene (1925)
Gopherus polyphemus	Florida, Georgia, Mississippi	Knipling (1937)
Terrapene sp.	Florida	Knipling (1937)
Testudo sp.	Texas (in a zoo)	Knipling (1937)
Terrapene carolina bauri	Illinois (in a zoo)	Rokosky (1948)
Terrapene carolina	Florida	King & Griffo (1958)
Terrapene carolina carolina	Virginia	Present report

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The Eye Lens Weight Technique in Aging of the Atlantic Croaker, *Micropogon undulatus*

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THE EYE LENS WEIGHT TECHNIQUE IN AGING OF THE ATLANTIC CROAKER, *MICROPOGON UNDULATUS*

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ABSTRACT The eye lens weight to age relationship was examined in croaker, *Micropogon undulatus*. Lenses were removed, fixed, and weighed using standard techniques. Age estimates were assigned based on total length measurements. Lens weight showed good correlation with total length. Age could be estimated by eye lens weight, but no more accurately or precisely than with length frequency analysis. Cumulative percent frequency analysis of lens weights showed distinct inflections in the curve, which correspond to hypothesized length at age points. The data seem to verify age structure based on length frequency analysis.

INTRODUCTION

The technique of using eye lens weight to determine age has been applied to a wide variety of animals with varying degrees of success. This method was summarized by Friend (1967). The species studied at that time were either mammals or birds. Since 1967 the technique has also been applied to some poikilotherms. The eye lens weight-age relationship was studied in the bullfrog, *Rana catesbeiana*, with some success (Bruggers and Jackson 1974). Freshwater drum, *Aplodinotus grunniens*, and carp, *Cyprinus carpio*, have also been aged using eye lens weight (Burkett and Jackson 1971; Carlton and Jackson 1968). These studies were successful in separating age groups, although overlapping year classes prevented the accurate aging of some individuals.

The Atlantic croaker, *Micropogon undulatus*, is the major component of the industrial bottomfish resource in the north central Gulf of Mexico and is, consequently, of considerable interest to resource stock assessment investigators. The occurrence and life history of the species has been discussed by several authors: Pearson (1928), Gunter (1945), and White and Crittendon (1976). I investigated the age-eye lens weight relationship in croaker to determine what relationship exists and whether this might strengthen the hypothesized age structure based on scale sculpturing and length frequency studies. Conventional scale and otolith reading methods have been moderately successful, but unverified. Well defined scale markings are present, but their interpretation is difficult. Otoliths are brittle and very hard to work with. There are no absolute means of determining the age of individual croaker, except to raise them from the postlarval stage.

MATERIALS AND METHODS

A total of 105 specimens were collected between September 15, 1976 and December 13, 1976, from industrial landings in Biloxi, Mississippi, from hook and line fish caught near the mouth of the Pascagoula River, and from catches southwest of the Mississippi River Delta by the NOAA research ship OREGON II. Individuals were selected from throughout the size range encountered. The selected commercially caught fish were removed from the conveyor as the boats unloaded and transported immediately to the Pascagoula Laboratory for body length measurement and removal of the eyes. All other specimens were worked up within one hour of capture. Sex was determined initially, but proved to be unimportant and was not noted in later samples. Eyes were placed in 10% formalin. The fixing and drying procedure followed that described by Carlton and Jackson (1968). Lenses were weighed every 36 to 48 hours until weighings differed by 0.2 mg or less. Paired lens weights were averaged and damaged lenses discarded.

Length frequency based formulas (Table 1) were used to assign an age to each individual. No formula was available for fish over 276 mm total length, so the age class 2 formula was applied to individuals larger than this. The data were examined by regression analysis for linearity. A graph of the cumulative percent frequency of lens weights was examined for possible age class boundary distinctions.

RESULTS AND DISCUSSION

Storage time does not seem to affect final lens weight. It has been demonstrated also that neither freezing nor

TABLE 1.

Formulas for computing estimated age at size for 3 age classes (Rohr, personal communication).

Age Class 0	
0–160 mm total length	$\text{Age} = \frac{\text{Total length} - 1.7428}{160.74}$
Age Class 1	
161–242 mm total length	$\text{Age} = \frac{\text{Total length} - 74.172}{82.021}$
Age Class 2	
242–276 mm total length	$\text{Age} = \frac{\text{Total length} - 181.92}{31.297}$

chilling have any effect on final lens weight (Longhurst 1964). Data from commercially caught fish can therefore be considered valid despite the lengthy time between death and preservation of the eyes.

Data from all specimens are plotted in Figure 1. No difference in dry lens weight between sexes was observed, so all data were handled in one group. Regression analysis shows a correlation coefficient of 0.9688 for the linear function Y = – 31.5509 + 0.3564 X. The range of lens weight increases with total length, but this can be attributed to normal deviation about the mean, as all data points fall

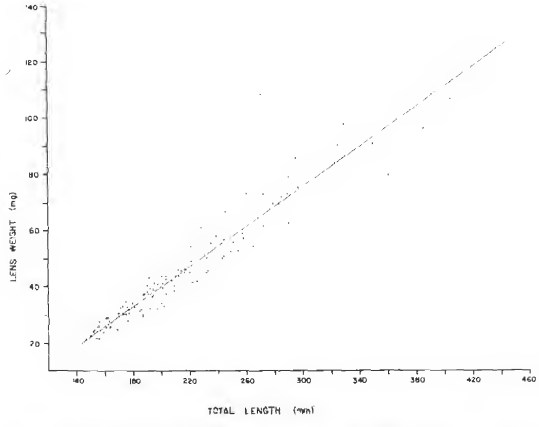

Figure 1. Data from 105 specimens of *Micropogon undulatus*. The solid line corresponds to the formula Y = – 31.5509 + 0.3564 X, Y = lens weight in mg and X = total length in mm. r = 0.9688.

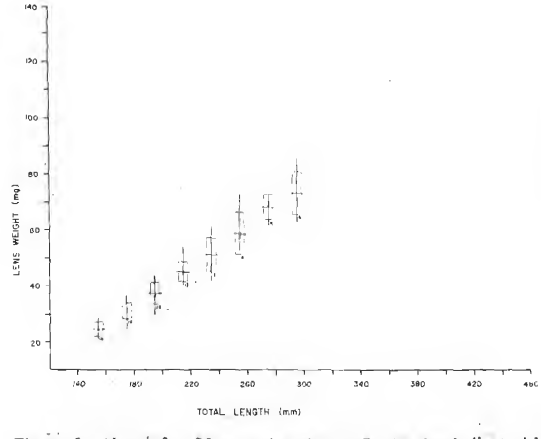

Figure 2. Means for 20 mm size classes. Rectangles indicate ±1 standard deviation while the solid lines represent the range. Numbers refer to sample sizes. In two cases, clumping of data and small sample sizes resulted in one standard deviation above or below the mean exceeding the range of the data. This was the case for size classes at the 255 mm and 275 mm points. Points above 305 mm were not sufficiently abundant for analysis. N = 96.

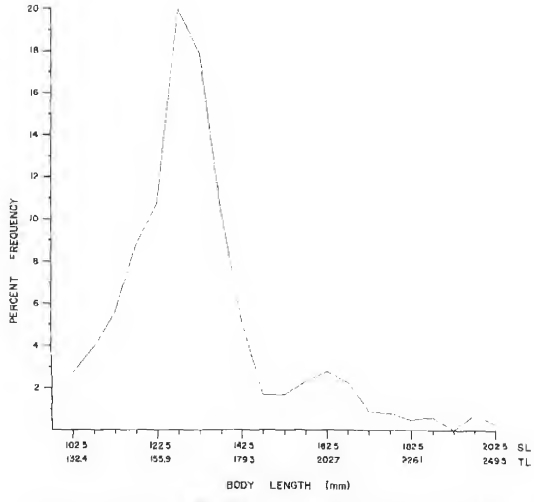

Figure 3. Length frequency distribution in 5 mm groups for November collections in the northern Gulf of Mexico over a 3-year period from 1973 to 1975. Both estuarine and offshore croaker populations were sampled. Original data were taken in the form of standard length measurements as indicated in the upper scale of the abscissa. This was converted to total length as shown in the lower scale for use in developing the length at age formulas. The left peak is age class I; the right peak is age class II. N = 4442 (Rohr, personal communication).

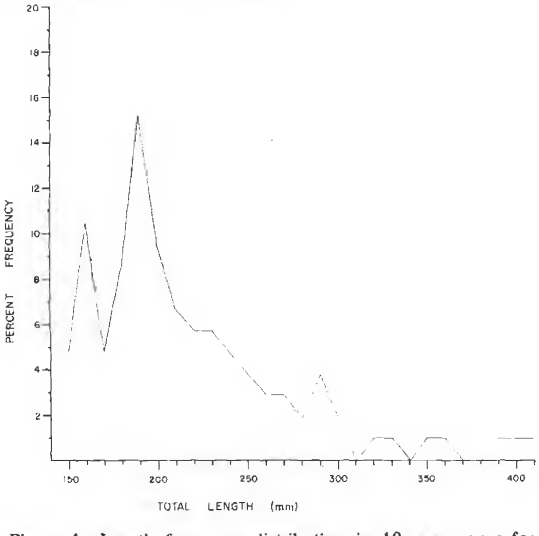

Figure 4. Length frequency distribution in 10 mm groups for croaker used in the eye lens weight investigation. N = 105.

well within two standard deviations of the mean (Figure 2).

The formulas used for age assignment are based on length frequency analysis of estuarine and offshore croaker samples collected over a 3-year period (B. A. Rohr, NMFS,

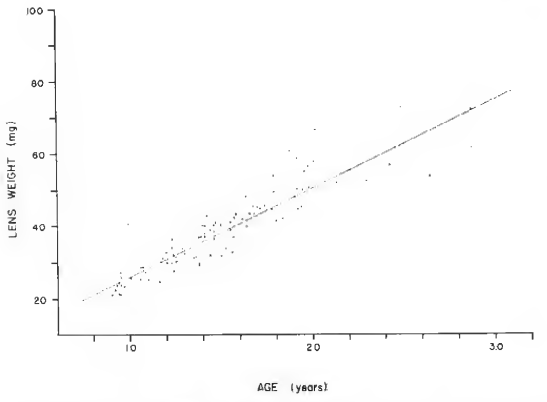

Figure 5. Eye lens weight-age relationship for 90 specimens. The solid line represents the regression formula Y = 1.3563 + 24.4925 X, where Y = lens weight and X = age. r ◘ 0.9109. Data points above the 3.0 year mark were not considered in the regression.

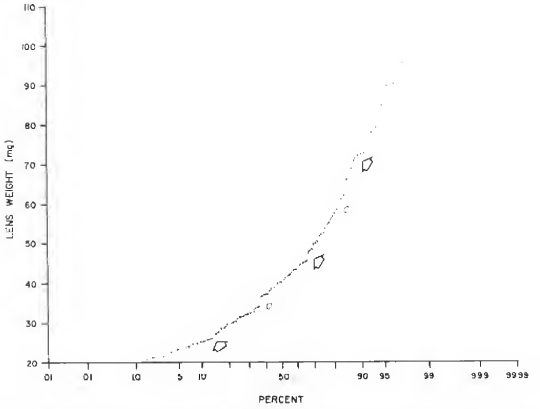

Figure 6. Cumulative percent frequency of eye lens weight. Solid lines represent best fit by visual inspection. Arrows show the major and minor inflection points as discussed in the text. One data point with a lens weight of 132.4 mg was not plotted. N = 104.

SEFC, Pascagoula, Miss). Figure 3 shows the length frequency distribution of this data for November collections. The length frequency distribution of the samples taken for this paper is shown in Figure 4. Even though this was not a random sample, the peaks of the year classes are similar to those in Figure 3. The populations can be considered of similar size and age composition.

Assigned ages are based on total length; therefore, a good lens weight-age relationship is expected. Analysis gave a best fit of the linear form X = Y − 1.3568/24.4925; X and Y representing age in years and lens weight, respectively (Figure 5). This is transformed from the original Y = 1.3568 + 24.4925 X, with a correlation coefficient of 0.9109.

The cumulative percent frequency curve of lens weights exhibits some interesting features (Figure 6). There are three obvious slope changes on this curve. Inflections are seen around the 26–27 mg, 46–48 mg, and 71–73 mg lens weight points. Interestingly, these closely correspond to the 1-, 2-, and 3-year points, respectively (Figure 5). It is difficult to draw definite conclusions from this analysis but age class boundaries are certainly suggested. If these data points are valid, this would verify the hypothesized age structure based on total length frequencies. Lens weight could then be used as an indicator of age in croaker. It should also be noted that there are minor inflection points and breaks in each of the three sections of the curve. In each a slight inflection is accompanied by a 2–3-mg shift in the line, distinguishing, perhaps, between the winter-spring and fall spawned groups of each year class.

Assuming the assigned ages used in this study are valid, age can be predicted from eye lens weight in croaker. Absolute age assignments based on eye lens weight are not possible at this time; however, age class boundaries are suggested. The eye lens technique is involved and time consuming, making it unsuitable for a population monitoring program. However, it does appear to be of value in supporting age assignments by other techniques.

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Notes on *Stenopus scutellatus* and *S. hispidus* (Decapoda, Stenopodidae) from Mississippi

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NOTES ON *STENOPUS SCUTELLATUS* AND *S. HISPIDUS* (DECAPODA, STENOPODIDAE) FROM MISSISSIPPI

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ABSTRACT Two species of *Stenopus* were collected in 1976 from a Liberty ship artificial reef near Horn Island, Mississippi. Six specimens of *S. scutellatus* were collected. This represents an occurrence record for Mississippi. Five specimens of *S. hispidus* were also collected; thus, extending the range in the Gulf of Mexico by about 400 km to the northwest.

Two species of *Stenopus* were collected during June through November of 1976 from an artificial reef located in the Gulf of Mexico (30°09′00″N, 88°44′50″W) approximately 10 km south of Horn Island, Mississippi. The reef consists of a scrapped World War II Liberty ship which was sunk on June 10, 1975, in approximately 14 m of water. This hull, designated the Waterhouse Reef, provides approximately 76,200 square meters of artificial substrate. Observations and collections were accomplished by employing SCUBA techniques.

Six specimens of *S. scutellatus* were collected (Table 1) from the artificial reef. In addition many other specimens were observed. They were most frequently seen in rock piles or under pieces of wood or pipe. Over half of those observed were egg-bearing females, easily distinguished by their bright green egg masses.

Previous Gulf of Mexico records for *S. scutellatus* include Rathbun (1919). Holthuis (1946, 1959), and Springer and Bullis (1956) from Florida, and Dawson (1963) from Louisiana. The present observations are the first records for Mississippi.

Five specimens of *S. hispidus* were collected during the study (Table 1). Others observed were most frequently seen on pipes or braces along the sides of the Liberty ship hull.

TABLE 1.

Date of capture, *in situ* hydrographic parameters, and carapace length of collected specimens of Stenopus.

Species	Date	Salinity* ‰	Temperature °C	Length (mm)
S. scutellatus	6/24/76	30	23.1	15.0
	7/7/76	38	23.0	16.5**
				16.0
	10/13/76	33	25.3	16.5
				17.0**
	11/3/76	30	19.8	17.5
S. hispidus	6/14/76	31	23.0	14.0
	7/7/76	38	22.0	15.5
				16.0**
				16.0
	10/13/76	33	25.3	17.0**

*By refractometer
**Ovigerous female

Again, over half were egg-bearing females, the egg mass of *S. hispidus* being bright blue.

Previous Gulf of Mexico records for *S. hispidus* include Holthuis (1946) from south Florida and Hopkins (personal communication) who found this shrimp on the Florida middleground (28°42′00″N, 84°26′30″W). The northernmost record for *S. hispidus* in American waters is from Cape Lookout, North Carolina (Kruczynski and Jenner 1969). Present observations extend the known Gulf of Mexico range about 400 km to the northwest.

Observations on the Waterhouse Reef have continued, but *Stenopus* have not been observed during the December 1976 through June 1977 period.

Limbaugh et al. (1961) reported behavioral differences between *S. scutellatus* and *S. hispidus*. According to their observations, *S. scutellatus* prefers to live in small holes or crevices and tends to be cryptic. They also stated that cleaning behavior of this species is restricted to small fish. *S. hispidus* on the other hand, prefers a more open existence living in large caves, and will clean small and large fish. These habitat preferences were noted during the Mississippi artificial reef study, but cleaning behavior was not observed.

Yaldwyn (1964, 1966) noted pair formation in *S. hispidus*. All specimens of *S. hispidus* and *S. scutellatus* on the Mississippi artificial reef were observed in pairs. It is difficult to speculate about the origin of the population of the two species of *Stenopus* found on the Waterhouse Reef. It is possible that the adult specimens developed from current-borne larvae. Little is known about reef-like habitats off Mississippi, and it is also possible that a permanent population of both species of *Stenopus* exists in deep waters. The Liberty ship artificial reef provides a substrate for many organisms previously thought to be uncommon off the Mississippi coast, and continued studies of the biota and ecological succession should be rewarding.

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Occurrence of the Brackish Water Asellote Isopod *Munna (Uromunna) reynoldsi* in Texas

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OCCURRENCE OF THE BRACKISH WATER ASELLOTE ISOPOD *MUNNA (UROMUNNA) REYNOLDSI* IN TEXAS

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ABSTRACT The asellote isopod *Munna (Uromunna) reynoldsi* Frankenberg and Menzies, previously known from coastal swamps at Sapelo Island, Georgia, is reported from Texas. Several specimens were collected in grab samples from Fence Lake, a small brackish marsh lake (salinity 0 to 2.7 ppt) in Sea Rim State Park, and in a nearby coastal marsh (salinity 4.4 ppt). The present records indicate that the species is a brackish water form.

INTRODUCTION

The genus *Munna* Kryer (suborder Asellota, family Munnidae) includes nearly 70 species of minute marine and brackish water isopods. The adequately described species are grouped into four subgenera (Fresi and Mazzella 1974). Seven species, all shallow-water forms, are assigned to the subgenus *Uromunna*, including the two temperate western North Atlantic species *Munna (Uromunna) hayesi* Robertson, from Port Aransas, Texas, (Robertson, in press), and *Munna (U.) reynoldsi* Frankenberg and Menzies, from salt marshes (among oak leaves) at Sapelo Island, Georgia, (Frankenberg and Menzies 1966). This report extends the range of *Munna (U.) reynoldsi* to Texas.

MATERIALS AND METHODS

M. (U.) reynoldsi was collected at two localities on the upper Texas coast approximately 10 to 13 km west of Sabine Pass (Figure 1). Twenty specimens were obtained on

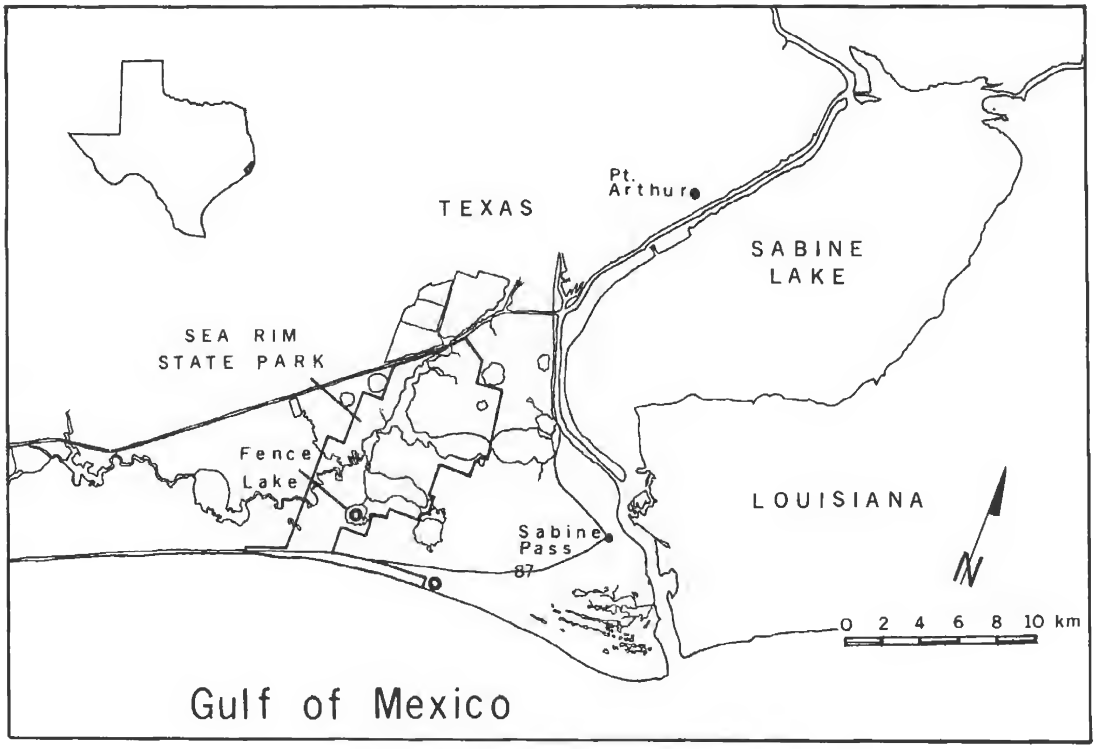

Figure 1. Collection sites (o) of *Munna (U.) reynoldsi* in Texas.

November 15, 1975 in Ponar grab samples in Fence Lake, a small brackish marsh lake north of Highway 87 in Sea Rim State Park. From November 1974 to November 1975 depth averaged less than 1 m; sediments were mostly soft mud, with much plant detritus near the margins; water temperature ranged from 13.8° to 34°C; salinity ranged from 0 to 2.7 ppt; and dissolved oxygen ranged from 5 to 11.3 ppm. Two additional individuals were collected on October 22, 1976 in a coastal marsh in Sea Rim Estates south of Highway 87, approximately 400 m from the Gulf beach. Because this marsh is elevated about 1 to 1.5 m above the level of the beach foreshore, it is flooded by seawater only during storm tides. The isopods were obtained in miscellaneous samples of plant detritus in water 10 to 20 cm deep. Temperature was 16.5°C, and salinity was 4.4 ppt.

RESULTS AND DISCUSSION

Stations were located throughout Fence Lake, but the species has been collected only in margin samples among plant detritus. Abundance, based on five samples which yielded specimens, ranged from 19 to 115 individuals/m^2. Major components of the associated macrobenthos included the polychaetes *Hypaniola florida* (Hartman), *Laeonereis culveri* (Webster), and *Boccardia* sp.; the oligochaetes *Limnodrilus* sp., *Aulodrilus pigueti* Kowalewski, and *Peloscolex* sp.; the amphipods *Corophium louisianum* Shoemaker and *Grandidierella bonnieroides* Stephenson; the isopod *Edotea* cf. *montosa* (Stimpson); and the chironomid larvae *Chironomus* sp. and *Endochironomus* sp.

The present data indicate that *M.* (*U.*) *reynoldsi,* like *M.* (*U.*) *schauinslandi* (Sars 1905) from Chatham Island and South Chile, is a brackish water species.

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Observations on Territoriality in *Alligator mississippiensis*, the American Alligator, and Other Points Concerning its Habits and Conservation

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OBSERVATIONS ON TERRITORIALITY IN *ALLIGATOR MISSISSIPPIENSIS*, THE AMERICAN ALLIGATOR, AND OTHER POINTS CONCERNING ITS HABITS AND CONSERVATION

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ABSTRACT Reasons are given for believing that charging alligators are serious, especially at their nests and in group defense of the young, rather than going through a "ritualized bluff." Observations are presented describing the actions of competing alligators and the establishment of territories between them in Mississippi brackish waters. Recent history has shown that alligators can live in natural streams and habitats close to human habitation, if they are not molested. The writer suggests that they should be removed from such environments when they attain a length of nine to ten feet because at that size they become dangerous. If man exterminates himself the various crocodilian species may survive for another quarter of a billion years as their ancestors have in the past.

In the early 1920's when Percy Viosca (1925) was prowling in a Louisiana swamp one night catching frogs with a carbide light, he was so threatened by a huge alligator that by his own admission he was temporarily scared out of his wits. In view of some questions raised about alligator behavior by Viosca and by others since that time, his account is worth further discussion even at this late date.

In spite of his cavalier manner of pointing at an unlabeled specimen in a bottle and saying thirty years later, for instance, I caught that snake on the Robeline road five miles west of Natchitoches on July 3, 1931, Viosca was widely recognized as a most careful field herpetologist (cf. Neill 1970, p. 65).

In the encounter described he established the fact that he was dealing with a very large and very shy and furtive alligator which apparently practiced complete avoidance of man when possible. Nevertheless, this beast (or another one exactly like it) charged from about 10 yards when Viosca scooped up two baby alligators about one foot long, and they gave the distress noise which he described as a grunt, "umph, umph." He thought this call was answered by the large animal before it charged, but he was not sure because of the subsequent excitement. He ran several yards through the foot-and-a-half deep water, fell over a cypress knee and doused his light. The charging animal did not attack in the dark and he told me many years later, "I never knew why that alligator did not grab me when I fell down." But there could be several reasons. In the first place the alligator may not have realized it was charging a man until it ran out into the light as Viosca (1925) suggested. Secondly, he threw the little alligators "right in the face" of the charger. No doubt the distress noises then ceased and a powerful stimulus stopped. At almost the same moment complete darkness supervened and the interloper suddenly disappeared from the alligator's view. This was enough to bemuse a reptilian brain and cause it to cease what it was doing without supposing something like the ending of a "ritualized bluff."

Apparently, the idea of a "ritualized bluff" arose because of the habits of alligator females of chasing molesters only a short distance away from a nest. The full length of such a run to the longest distance recorded in the literature is about 40 yards (see Kushlan 1973). There are good reasons for short runs. In the first place the alligator is not built to run a mile. Secondly if one left a nest for long, a second egg stealer might come along. Thus a short run is in the best interest of nest protection.

The Everglades Seminoles are said to have a rule that if an alligator is moving, stay out of the way. Several accounts of alligator attacks resulting in serious injury and a few deaths of people have been recorded in recent years (cf. Neill 1970). These all involved hungry animals so far as is known. Anyway it is well known that alligators will bite. To assume that a charging alligator will not bite because it is only bluffing when guarding a nest seems to me, highly dubious. Much more likely such animals are not known to attack successfully only because they have not been known to catch their men, or in one sense their integrity has never been questioned.

Viosca said that he was puzzled because there is no real evidence of parental care after the young leave the nest. But the later observations of Joanen (1969) and Kushlan (1973) are good evidence of parental care in the alligator, and since these words were written Hunt (1977) has described the general response of older Morelet's crocodiles to mistreatment of young by other individuals in experimentally staged situations. There is a growing body of evidence that diverse crocodilians watch out for the young as a group, not just as parents. Furthermore, in some species mothers help the young out of the nest and carry them to water when they hatch, see Hunt (1977) for a literature summary.

Viosca's whole episode could have taken place on the basis of general reaction to a distress noise. Neill (1971)

described the use of the distress signal in various crocodilian species. It has been observed here at least once. One of our staff members once fished while standing in one of the ponds on Horn Island where he hooked a small alligator which came to the top. It made a strange noise which was described as a buzzing sound, whereupon alligator heads began to pop up all over the pond and converge on the area. The fisherman cut his line and got out of the pond. This is interesting because several alligators were not a parent and this indicates group care and protection.

Alligators have lived under essentially three regimes during the past 485 years, so far as their relations to man go. Before the European came, the Indian tolerated the alligator and in general left it alone largely because it was considered to be harmless and relatively valueless. A few were killed occasionally for their teeth and for the flesh, which is quite edible. There was no strong interest shown in their hides. Thus Le Page du Pratz (1758) tells the story of an amused Indian woman in Louisiana who taught a frightened Frenchman to chase an alligator out of his camp with a fallen tree limb.

The live-and-let-live relationships of the alligator and man changed to what may be called the persecution stage, during which the alligator was killed for its hide or wantonly shot and killed for the mere love of killing. That process has gone on for four hundred years at least as the European and his society took over the country.

During the zenith of the persecution stage, when I was a boy, I saw my uncle shoot a small alligator out in the middle of the Salt Works on Saline Creek near Goldonna, Louisiana, it being the only one that had been seen in that area for several years. One would think a dragon had come into the country. Some years later in the early 1940's once I accompanied a group of game wardens of the old Texas Game, Fish and Oyster Commission as they went killing alligators for fun on the bayous of the Texas Coast. Carcasses were not saved.

During this period the alligator has been taught its place, so to speak. It is now mostly a furtive hunted creature, apparently recognizing quite well that man will kill it almost every time it shows itself. Neill (1971) commented on how quickly a population becomes wild when a few are killed.

Before this age of persecution it can be assumed that these animals were bolder. My grandfather, James M. Pennington, once killed a large alligator by shooting it in the mouth as it charged him across a small creek in Louisiana well over a hundred years ago. He was not the aggressor. For this reason it never crossed my mind to doubt William Bartram's (1791) story of his boat being chased by alligators in Florida. Bartram was a Quaker who quaked at few perils, so far as the record goes, and if he stated clearly that he was chased by alligators, I am inclined to believe him, although Neill (1971) calls this part of a "farrago" of dubietys. Strangely enough later in his book Neill seems to accept the attack on Bartram as being true. Alligators grew much larger in those days and one seventeen feet long would have weighed around 1400 pounds. They were the largest thing in the woods, except when the buffalo wandered through, and one might say they were accustomed to chasing whatever they pleased.

In 1964 at a meeting of the American Society of Ichthyologists and Herpetologists in North Carolina I heard Dr. Francis Harper commend the "civilized and progressive" states of Alabama and Mississippi for their laws protecting alligators. Today everybody including the federal government has followed Mississippi and Alabama and today we have protective laws for the alligator.

Alligators have been present in and around this Laboratory to my knowledge since 1955, and presumably for eons before. They are in the completely wild condition except that they are not persecuted and occasionally they are fed fishes by students returning from field trips.

When fish are thrown to them they do not jump forward in the water, and apparently cannot do so, but they lash out quickly from the side and grab with the mouth while simultaneously arching the tail around on the same side.

Alligators that are at the surface often miss fish that are thrown to them. These may sink within a few inches of their snouts or eyes with the alligator unaware and acting stupid. On the other hand they strike at floating fish quite adeptly. Evidently the surfaced animals with eyes out of the water, in the typical alligator floating stance, can see in the air only and not below the water, nor do they bob their heads up and down to facilitate such vision. Their habit when at the surface is to concentrate on what is visually possible to them above the water and on shore; they lie there unmoving and apparently no more noticed or noticeable than a small log by the ordinary denizen of the bayous.

Usually the alligator is the largest animal in his environment, but not always. No doubt the alligator gar, *Lepisosteus spatula*, can make away with small alligators but these gars apparently are not greater in size than a little over five feet on the Gulf Coast, none equaling the 9'8 1/2" specimen listed and figured by Gudger (1942) in fresh water. At least that has been my observation in the past 47 years. Lastly there are the snapping and alligator snapping turtles which can take any alligator that does not outweigh them, in my opinion. The largest we have seen on the Gulf Coast was a snapping turtle (*Chelydra serpentina*) almost two feet long, which was dug up alive, buried about two feet deep in the bottom of an artificial fish pond on the Laboratory grounds following the fearsome hurricane Camille of August 18, 1969. Apparently it was aestivating through the summer.

But there remain the alligators themselves. According to Neill (1971) they do not fight much in the wild, but this is not an absolute dictum and he gives a picture of two animals killing a third.

The main boat slip of this Laboratory is a dug channel where a former stream ran down some 160 yards to meet Halstead Bayou. It is 17 yards wide. The water is brackish and supports oysters and barnacles much of the time. This slip was the home of one of the local alligators for some three years and it had grown to a size close to six feet in length. Then one day another animal about half that length showed up at the head or inner part of the slip. This apparently infuriated Albert, as our resident alligator was named. There was no surface action, but I saw Albert go under water some 30 yards away while the smaller animal lolled at the surface as if it had not a care in the world. I tensed up and said to myself, "You fool, don't you know he is coming after you," when it gave a swirl and disappeared under the water. A little later, to my relief, it appeared some 30 or 40 yards downstream, while Albert came up at the head of the slip and obviously was looking around. The same tactic was used a second time, but the smaller alligator came back to the head of the slip where it was "cornered," so to speak, but it did not seem to mind. On the third repetition of these tactics both animals disappeared and stayed under longer than my patience lasted and so I went away. The upshot was that within the next two days the smaller alligator moved down near the mouth of the slip and took up residence close to the bayou, while Albert remained at the head of the slip, which seemed to be the poorer location, and there was no more chasing.

From this I concluded that the smaller alligator was able to take evasive action under the water to avoid the larger one and was confident that it could do so. Anyway, it showed no fear of an animal that outweighed it about seven times. I do not know what this evasive action is but I do not see how it could be faster swimming speed. Secondly, it would seem that the alligator at the surface senses in some manner when another one approaches through the water below.

I took these observations also as evidence of "territoriality" in the American Alligator, a common affair in many organisms, and did not realize that the situation was unknown until I read Neill's (1971, p. 61) statement, ". . .; indeed, the existence of territoriality has never been demonstrated for any crocodilian. . .". Therefore, I resurrected the observations and present them for the first time.

Large alligators do not grow in great numbers nowadays. Barbour's (1933) figures show, by extrapolating from a skull, that the largest modern American Alligator he had a record of was 17.5 feet long. He saw this animal when he was a boy. Neill (1971) mentioned one said to be 19 feet long. The largest recent specimen from this coast was caught inadvertently in Bayou Bernard in a trammel net by staff members of this Laboratory on September 21, 1967. The animal drowned. The measured length was 9 feet and the weight was 214 pounds. The mounted specimen now rests in the University of Alabama Zoological Museum. Larger specimens have been seen near the Laboratory in Davis Bayou but none have been taken.

The future of the alligator can be considered in two aspects, the first one being the temporary or present preservation of the species. The recent experience in Louisiana, Mississippi, Alabama and Florida indicates that mankind can live around and with a population of alligators in nearby waters. On the other hand it is probably not feasible to allow animals in such populations to grow to large sizes and certainly not to the limits known to Barbour (1933) and Neill. These animals would weigh up to 1500 pounds and they are simply too dangerous to be maintained where man comes and goes. Thus these animals should be eliminated after they get to be about ten feet long, which is still a very large animal for man to encounter in the water in case of an attack. Either that or they must be removed to the most remote swamps where man goes at his risk.

And so the alligator seems to have lived through to a period of peace and it may live on a few hundred years before it becomes extinct. W. T. Neill seems to think an early demise is inevitable for all crocodilians, but this may not come to pass if in the meantime man exterminates himself. In that case these reptiles may make it through to the millenium and live on for another quarter of a billion years when no man exists. In that case they will owe to man their long peace, when no vast technological civilization arises to endanger them again, because man will have used up the easily available materials (metals and fossil fuels) which it takes to begin such developments. In brief, both man and the crocodilians are in last chance positions with regard to survival on the Earth. Man can change his fate, but the crocodilians are helpless.

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Notes on the Status of the Gannet (*Morus bassanus*) in the Gulf of Mexico, with a Record from Mississippi

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NOTES ON THE STATUS OF THE GANNET (*MORUS BASSANUS*) IN THE GULF OF MEXICO, WITH A RECORD FROM MISSISSIPPI

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ABSTRACT The Northern Gannet nests on rock cliffs in the north Atlantic and winters as far south as Yucatan on the west, and N.W. Africa on the east. The birds are not known to cross land and seem to fly around Florida to enter the Gulf of Mexico. Most numbers have been reported off Louisiana, Mississippi, Alabama and the Florida panhandle. Numbers in the western Gulf seem to be few. There are 12 skeletal parts or skins of Texas gannets in museums in Texas and Louisiana. Two specimens have been collected in Louisiana, only one of which is known to remain. There are 6 specimens from the Mississippi coast (one from the high seas) in Mississippi and Louisiana museums, none from Alabama and 10 from south Florida. Gannets have been reported previously from the Gulf in every month but August. A live specimen was taken in Mississippi Sound on August 10, 1977 following heavy squalls. It was immature. It died on the same day. The skin was deposited in The Fannye A. Cook Memorial, the Mississippi Museum of Natural History, cataloged as Ab 5019.

GENERAL REMARKS

It has been said that "...so little is known about the real distribution of seabirds over the Gulf that in many cases their very presence is merely inferred from their occurrence in coastal situations after storms," (Lowery and Newman 1954). This is true, of course, and the only gannet the senior author ever saw previously (Gunter 1945) was caught after being blown into a fish house during a spell of heavy weather in south Texas. The present account also concerns a gannet taken following gale winds on Mississippi waters. First, however, we would like to review the whole situation regarding gannets in the Gulf as a background to the full import of this record.

According to Arthur (1931) the word gannet is derived from the Anglo-Saxon word *ganot* for sea fowl or fen duck. He adds that the species name *bassanus* is derived from the Bass Rocks of the Firth of Forth in Scotland where the bird nests in great numbers. The generic word *Morus* seems to be derived from the Latin word for fool and relates the gannet to the boobies. These short-legged birds sprawl about clumsily and, by anthropocentric attribution, stupidly on land. They are obviously made for the water and the air and not the land.

Gannets have three separate antipodal populations, one from the North Atlantic ranging to the Tropic of Cancer and beyond in the winter; one around the southern half of Africa ranging north to the Equator; and the third around New Zealand and the southern half of Australia, see A. W. Schorger and R. S. Palmer in Palmer (1962). The three populations are classed as subspecies of *bassanus*. In terms of that usage the Northern Gannet is *Morus bassanus bassanus* (Linnaeus).

It should be noted, however, that in reference to the Northern Gannet, Oberholser (1974) says "No subspecies." He had firm opinions about avian taxonomy based on reasons he usually expressed clearly, but in this instance his reasons are unknown, although the implication is that all three populations are full species.

The Northern Gannet nests on the cliffs of rocks and islands in the Gulf of St. Lawrence and off Newfoundland and Iceland, the Faeroes and the British Isles and it winters south to Florida and the Gulf of Mexico on the west, and on the east to the Azores, Canary Islands, North Africa and the Mediterranean (cf. Palmer 1962 and Oberholser 1974).

Palmer states that although the birds are usually found out of sight of land that they do not often get beyond the continental shelf. This is to be expected for during the past 50 years marine biologists have learned that the great abundance of life in the oceans extends from the shore to the edge of the shelf with the great depths and the mid-ocean surfaces being relatively barren.

It is worth remembering that Oberholser says the gannet is the most spectacular bird in the chill gray North Atlantic and that these waters have been known poetically for 10 centuries as the Gannet's Bath. Even so, the gannet is a predatory fisher and in the winter it must go south to where the fishes are found near the surface. The bird is a high diver and goes in from altitudes of 3 to 100 feet; under water it is generally a shallow swimmer although it has been caught in nets as deep as 14 fathoms (Oberholser 1974).

GULF OF MEXICO RECORDS

Texas

Oberholser says the gannet comes rarely to Texas. He says there are 25 definite records on the east Texas coast but only 2 on the south Texas coast, and that it is uncommon in the western Gulf, although it was reported once from Veracruz, Mexico. However, this account is a bit garbled and in the fine print, so to speak, Oberholser lists 10 specimens now extant in Texas, either as skeletons, a skull or skins, at the Texas A&M Museum of Vertebrate Zoology, the Texas A&I University at Kingsville, the Corpus

Christi Museum and the Welder Wildlife Refuge collection. These were all taken since 1966 and 7 of them come from south Texas and only 2 from east Texas. Oberholser further lists 7 specimens that were carefully identified but not saved. These include 4 specimens from Galveston County and Jefferson County (east Texas) and 3 from Aransas County and Nueces County including the 1944 specimen the senior author reported (Gunter 1945).

The privately printed publication by Hagar and Packard (1952) covers some 17 years of intensive bird observation in Aransas County and nearby in south Texas by two master observers. The gannet was seen twice. It must be noted, though, that these two observers did not go often to the barrier islands and made most of their observations of seabirds from the mainland shore.

In a telephone conversation of October 6, 1977, Dr. George H. Lowery, director of the Museum of Natural History at Louisiana State University, informed the senior author that the Museum had two skins from Galveston, Texas. He stated that it also had one specimen from Norway. Counting these 2 Louisiana specimens there are 12 specimen records of gannets taken from Texas in museums in the Gulf States. Oberholser listed at least 43 sightings by authoritative observers and the number seen must have been considerable.

We have made no attempt to find out what Texas gannet specimens might lie in other museums of this country.

One gathers the impression that Oberholser's ideas about scarcity of gannets in the Western Gulf are correct and that they are based chiefly upon the numerous sightings of several birds at a time on the east Texas coast and even farther east, the likes of which have not been reported in south Texas. It should be noted that these south Texas reports and records are from the western Gulf at about the latitude of Tampa and Hollywood, Florida; and so it may be said that the Northern Gannet is a visitor in small numbers during the winter in the western Gulf of Mexico.

Scarcity of these birds in the western Gulf apparently comes about because they all come down the Atlantic coast and are not known to cross the continent or even the Peninsula of Florida while coming from their nesting rocks to the Texas coast. Lowery (1974) reported seeing these birds off Yucatan, which is the most southerly sighting recorded so far as we know.

Louisiana

In Louisiana, Beyer (1900) indicated that gannets were quite common around The Rigolets in the latter 1800's and he listed a collection made on December 9, 1886. This specimen presumably rested at Tulane and Lowery (1974) says 88 years later that it remains the only record from the state, although the birds are quite often seen off the mouth of the Mississippi River.

Arthur (1931) says that the gannet is rarely seen in Louisiana and then is usually found with a number of its fellows. In that volume, of which he was largely the compiler for the Louisiana Department of Conservation, an unlabeled photograph of what apparently is a well-mounted bird is presented at the head of the section on Sulidae, the boobies and gannets. It seems to be an immature gannet standing on the edge of a marsh. The habitat is unlikely for a bird that hatched out on a towering rock cliff in the cool temperate zone, but as gannets do come to the Louisiana coast some of them inevitably end up in the marsh. In any case the plumage pattern corresponds well with what Oberholser (1974) ascribed to a well-advanced immature bird. In a letter dated August 24, 1977 Mr. Gene Stock of the Louisiana Wildlife and Fisheries Museum, which essentially is a collection of mounted birds in New Orleans, informed the senior author that there is no gannet in that collection at present. The source of Arthur's photograph is unknown.

Oberholser (1938) adds nothing to the previous information on Louisiana gannets except to say that several specimens were "taken" formerly at The Rigolets as stated by Beyer (1900) but none were saved except the one specimen noted.

Lowery and Newman (1954) state that gannets have been seen "between . . . the Mississippi Delta" and Yucatan, and say there is one definite record from Louisiana, apparently in reference to Beyer's specimen. Lowery (1974) repeats the statement about one specimen and says that he was the observer on the Mississippi River-Yucatan transect.

In the telephone conversation noted previously, Doctor Lowery stated that the Louisiana State University Museum of Natural History had acquired a specimen from Grand Terre, a barrier island off the Louisiana coast in Jefferson Parish, taken on January 27, 1970 and which is now specimen number 68101, a skin, in the Museum. So after a lapse of almost 85 years Louisiana has acquired a second local gannet specimen. Inquiries to Tulane about Beyer's now aged specimen have gone unanswered.

Alabama

Lowery and Newman (1954) say there are three definite records for Alabama. Imhof (1962) lists gannets at Gulf Shores, Sand Island Light and an exhausted bird at Fort Morgan from November 1957 to September 1960. These records could not be the ones referred to by Lowery and Newman (1954). Imhof says gannets are commonly seen offshore from 100 yards to 5 miles off the Gulf beach east of Mobile Bay. He lists 103 seen off that coast and Dauphin Island on April 21, 1956. None of these have been listed as collected specimens.

Dr. H. T. Boschung, director of the Museum of Natural History, University of Alabama, notified us in a letter dated September 27, 1977 that the museum staff members were not acquainted with any anatomical relict of a gannet in Alabama.

Florida

With regard to Florida, Lowery and Newman (1954) say there are four definite records from the Dry Tortugas and vicinity. They say gannets are commonly sighted from the Pensacola Beach where F. M. Weston has reported 51 in a 45-minute period.

Dr. O. T. Owre of the University of Miami Ornithological Collection informed me in a telephone conversation on September 13, 1977 that there were four skins in his collection all from south Florida.

It is apparent from the accounts given above concerning eastern Texas, Louisiana, Alabama and north Florida that gannets are quite common and sometimes are seen in large numbers in the offshore waters of the northern Gulf of Mexico. It follows that if the surmises concerning gannets not flying across continental land are correct, even including the Peninsula of Florida, then the waters of the Keys and the southern tip must contain an abundance of these birds at certain times of the year as they go around Florida to enter the Gulf of Mexico.

Mississippi

In Mississippi records of the gannet are rather scarce, and Burleigh (1944) did not list the species. Insofar as our coast is only 68.8 airline miles from east to west (Gunter 1976), and gannets have been recorded only a few miles to the east and west, we could rest content with the general statement of Lowery (1974) who said that the gannet moves southward along the Atlantic coast in winter and quite a few enter the Gulf of Mexico, arriving as early as September and leaving as late as May 14. However, there are other concerns.

Lowery and Newman (1954) say there is one record for Mississippi and this apparently refers to a sight record, as noted in the following quote from Williams and Clawson (1963, p. 190):

> Although the Gannet is regularly found in the Gulf of Mexico in witner and early spring, it had been reported from Mississippi waters only twice before the winter of 1960–61. G. H. Lowery, Jr. and R. Newman (U. S. Fish and Wildlife Serv., Fishery Bull. 89: 524, 1954) mentioned one record and F. C. James (Aud. Field Notes, 14: 315, 1960) reports 54 seen by John Walther and J. M. Valentine on 15 March 1960, between Ship Island in Mississippi and the Chandeleur Islands in Louisiana. In 1961 several sightings were reported, including 43 seen in Mississippi Sound on 16 January by H. D. Haberyan (Newman, Aud. Field Notes, 15: 335, 1961).

These authors go on to say that on February 12, 1961 they found hundreds of gannets one to ten miles south of Horn Island and took two specimens. One was an adult male taken three miles south of Horn Island. Gandy and Turcotte (1960) list the first bird as Ab 4842 from Harrison County (it should be Jackson) in the Fannye A. Cook Memorial Museum in Jackson, Mississippi. Another was said to be eight miles farther out (which was beyond the waters of the state). It went to the Louisiana State University Museum. The same authors reported the gannet as abundant as before in the same area on February 24, 1962. Another bird taken by Clawson on the east end of Petit Bois Island on February 24, 1962, is Ab 4815, in the Fannye A. Cook Memorial Museum. They reported a juvenile 150 yards from the mainland near Biloxi on March 31, 1962. Both of the collected specimens were listed as skins in the collection of the Fannye A. Cook Memorial Museum by Gandy and Turcotte (1970).

In the telephone conversation noted previously, Dr. George H. Lowery, Jr. mentioned the two Mississippi collections now in the Louisiana State University Museum taken by Williams and Clawson (1963). One was taken near the west tip of Horn Island and the other was from eight miles south of Horn Island, mentioned above.

In a letter dated September 28, 1977, Dr. M. Ralph Browning stated that there were no specimens of the gannet from Alabama, Mississippi or Louisiana in the National Museum of Natural History.

This summarizes recorded information on the gannet in Mississippi waters. Hundreds are seen at times in midwinter and four were collected in February 1961 and 1962. There are no other printed records.

A NEW MISSISSIPPI RECORD

On August 10, 1977, a Mississippi sports fisherman, Hiram (Mack) Jones notified the Laboratory telephone operator that he had in his possession a disabled, strange bird at the Gulf Park Marina near Ocean Springs. It had been taken from Mississippi Sound earlier that day at approximately the mid-point of a line between the west end of Horn Island and the east end of Deer Island, in Jackson County. Jones described the bird as floating high in the water with dry plumage. At the time of its discovery, it would occasionally lapse into a convulsive state with much coiling of the neck and vigorous gaping. When the bird was taken from the water, it stabilized momentarily and escaped, flying approximately 10 meters, whereupon it resumed the convulsion. The bird was retrieved and brought to the marina near Ocean Springs. The writers visited the marina at about 11:30 a.m. and saw the bird, a gannet, which appeared to be alert and strong a few hours after its capture. It yakked at us quite loudly, disproving the statement of Oberholser that they appear to be vocal only on the "gannetry," and bit the junior author hard enough to cause a wound when he force fed it the tail of a penaeid shrimp. We left the bird with Mr. Jones and hoped that it would recover for it had no apparent injuries. Nevertheless, within a few hours it was dead. Jones said that it was infested with minute "ant-like" ectoparasites and he applied a liberal

quantity of Sevin pesticide dust. Shortly after the bird succumbed. Sevin is fairly mild and we doubt that it killed the gannet.

It was conjectured that the bird had been injured by dashing into a large submerged object during the course of feeding or that it had been buffeted about by local squalls. Seas were estimated by Jones to be running up to 3 meters high in Dog Keys Pass on that date, and the force of the wind was sufficient to blow the top off these waves, suggesting winds from 30 to 40 knots. These high energy winds were from the southeast. Weather records of the Keesler Air Force Base at Biloxi showed winds up to about 35 knots at about the time of the capture. Large squalls were present on the Gulf coast at this time.

Morphometrics of the specimen include a total wing span of 170.4 centimeters at full extension and a total extended length of 89.5 centimeters. The weight of the bird was not ascertained for it had been eviscerated earlier by a team of zealous parasitologists at this Laboratory.

The color was that of an immature bird; the back and wings were a light grayish brown with no speckles and the lower parts were dull white. The upper wings and a connecting stripe across the back were darkest. There were no white splotches on the back and the bird seemed to be a second year immature or second winter bird, as described by Oberholser (1974), or possibly even more advanced.

Most gannets of the Gulf of Mexico are immatures, and Weston (see Lowery and Newman 1954, p. 524) has estimated that the ratio is twelve immatures to one adult. According to Van Tyne and Berger (1959), studies by A. Landsborough Thomson on British gannets have shown that the younger birds migrate the greatest distance seasonally and the mature birds stay closer to home. If this situation holds among the western gannets it will skew the distribution of old and young from north to south, and there should be a greater number of mature gannets on the Virginia coast and northward in the winter than is found in the Gulf. On the other hand, this may not show in collections because collectors probably select the fully mature, white birds.

Gannets have been reported previously in the Gulf every month except August and with this specimen that monthly gap is filled. Insofar as plumage pattern is that of a second winter bird or later, the question arises as to whether it is an early migrant or a lingerer from late spring. The weather might be invoked, but which way? The Gulf and Caribbean waters were cooled during the last severe winter to the extent that no strong West Indian hurricanes and only one small weak one developed in 1977. On the other hand during August 1977 official temperatures of 20°F befell parts of the northern United States. The first situation would cause gannets to linger on in the Gulf presumably, while the second would drive them south very early in the season. Which case is correct for the specimen at hand, is not known.

This specimen is now deposited in the Fannye A. Cook Memorial, the Mississippi Museum of Natural Science in Jackson, Mississippi, where it has been made into a skin cataloged as Ab 5019.

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ACTIVITIES OF THE GULF COAST RESEARCH LABORATORY DURING FISCAL YEAR 1976 –77: A SUMMARY REPORT

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ADMINISTRATION

This year was an austere one in Mississippi for all state-supported institutions of higher learning, with the Gulf Coast Research Laboratory (GCRL) receiving the same allocation ($1,390,318) as last year for general support. This was augmented by a Special Library Improvement allocation in the amount of $25,000 appropriated by the 1976 State Legislature and by $210,794 generated by research grants and contracts.

As is the case with most growing institutions, the expansion of the physical plant has not kept pace with the increases in staff and activities. Therefore, the condition of "cramped quarters" has become an outstanding campus-wide problem that has caused a spillover of activities into the passageways. However, some relief appears imminent with the possible approval by the 1978 Legislature of the Laboratory's request for construction funds of the Marine Education Center Building on the Point Cadet, Biloxi, Mississippi, campus. The Board of Trustees designated this proposed building as number two in their list of priorities for next year's Capital Outlay for State Institutions of Higher Learning.

RESEARCH VESSEL

Last year, International Marine Fabricators, Tampa, Florida, under contract with the State Building Commission, went out of business leaving unfinished the 85-foot oceanographic research vessel under construction for GCRL. Following a thorough study of the problem, the State Building Commission requested, and the 1977 Mississippi Legislature approved, the appropriation of $525,000 with which to complete the vessel. Mr. Eric Allan of Schuller & Allan, Inc., Houston, Texas, was appointed as the marine architect to improve the vessel design, prepare bid specifications and oversee the completion of the project. The vessel is expected to be in the water and working sometime during the next year.

BOAT OPERATIONS

Boats that provide essential services include the 65-foot GULF RESEARCHER used in both the Laboratory's research and educational programs, the 38-foot steel trawler HERMES used principally in the educational program, four diesel-powered cabin workboats, and some half-dozen Boston Whalers and other miscellaneous smallcraft powered by outboard motors. The larger vessels are operated by six full-time boatmen, two of whom are licensed Masters for vessels of up to 100 gross tons. The Boston Whalers and other smaller miscellaneous boats are operated on a part-time basis by scientists and technicians to meet the needs of ongoing research projects.

During the year GULF RESEARCHER was at sea for 47 days and 19 nights. HERMES spent 71 days at sea and the smaller boats made innumerable trips during the same period.

RESEARCH

Research activity increased somewhat during the year with the main thrust continuing in fisheries and environmental studies.

A contract was executed with the E. I. duPont de Nemours and Company to conduct an environmental baseline study of St. Louis Bay with field sampling to begin in the fall of 1977. The objective of the study is to generate a comprehensive data base on the ecological characteristics of the Bay estuarine system for DuPont and Mississippi. This study, funded in excess of three-quarters of a million dollars, was sought by DuPont in connection with the construction of their titanium dioxide manufacturing plant near the shoreline of the Bay. The plant is anticipated to be operational in 1979.

The Bay study will be done by 12 senior scientists and about 25 technicians from the sections of Physical Oceanography, Fisheries Research and Development, Microbiology, Anadromous Fishes, Botany, Analytical Chemistry, Environmental Chemistry, Geology, Ecology and Fisheries Management. Dr. Robert A. Woodmansee, head of the Ecology Section, is project coordinator.

A few projects for each research section are described briefly below.

ANADROMOUS FISHES SECTION, Mr. T. D. McIlwain, Head

Development of Gulf Coast Artificial Reefs (Funded by Mississippi-Alabama Sea Grant Program and GCRL): The states of Mississippi and Alabama have placed ten surplus Liberty Ship hulls in seven locations off their coasts. Five ships have been sunk off Mississippi in two locations. The two Mississippi reefs, monitored biweekly by personnel from Mississippi are assessed by diver survey and sportfishing methods. Divers are documenting the effects of the ships in

establishing a new reef community in the northern Gulf.

Rearing and Stocking Striped Bass–Mississippi Gulf Coast (Funded by National Marine Fisheries Service, U. S. Fish and Wildlife and GCRL): A new three-year striped bass project was begun in September 1976. The objectives of this program are to establish (by stocking) a striped bass population in Biloxi Bay, to stock sea-run striped bass, to determine their success, and to establish a source of fry from Mississippi brood fish.

A total of 407,583 two-inch striped bass of South Carolina origin were reared and stocked into Biloxi Bay. Of those fish, 18,808 were reared from eggs taken from Mississippi brood fish. These brood fish were taken in Pearl River near Jackson, Mississippi, by Mississippi Game and Fish Commission personnel and transported to GCRL for spawning. Out of four eligible brood fish two were tank spawned, one successfully. The successful spawn resulted in 100,000 fry. Fifty-thousand were retained for rearing at the Laboratory and the remaining 50,000 were returned to the Game and Fish Commission for rearing in ponds near Ross Barnett Reservior.

Almost 8,010 sea-run striped bass were stocked into the St. Louis Bay system. Fourteen striped bass–fish stocked in previous years–have been returned to project personnel. These fish range in weight from one-half pound to twelve pounds.

A sampling program is in progress to check for natural reproduction of previously-stocked bass and occurrence of juvenile striped bass, and to monitor previously-stocked striped bass in order to continue assessing the results of all bass-stocking programs previously carried out in this area.

Artificial Midwater Reef Development Program (Funded by Mississippi Marine Resources Council): This program was carried out in conjunction with the Gulf Coast Artificial Reef Development Program. Multi-array fish attractor devices consisting of ten-foot lengths of two-inch PVC pipe were installed on the Liberty Ship hulls sunk at reef site FH–3 in the Gulf. These devices congregated schools of bait fish over the reef site and attracted large schools of desirable game fish (Spanish and King mackerel, jacks and little tunny) above the reef site. This resulted in an increase of angler creels at the reef site.

Bait Fish Rearing (Funded by Mississippi Marine Resources Council): A handbook is in preparation detailing the techniques for rearing bullminnows to supply the live-bait industry along the coast. Bullminnows are currently supplied to the retail market by a few fishermen using traps and/or hook and line. The bullminnow is a favorite live bait used by coastal sport fishermen. Supplies are quickly depleted in late fall when the spotted seatrout (*Cynoscion nebulosus*) are running.

ANALYTICAL CHEMISTRY SECTION, Dr. Thomas F. Lytle, Head

Nutrient Study in Coastal Waters Near Areas of Offshore Oil Drilling (Funded by the Bureau of Land Management and GCRL): As part of a National Science Foundation cruise in April 1977, water samples were collected in a time series study at a location 90°W, 28°N in Louisiana coastal waters. All nutrients and various forms are being measured to determine the diurnal cycling of nutrients and also to detect any possible effect on nutrient loads and distribution by the petroleum pollutants which were readily detected in the sediments of this area.

Studies of Chemical Constituents of Mosses, Fungi and Lichens (Funded by GCRL): Mosses, fungi and lichens were a dominant form of life 300 million years ago. A chemotaxonomic and geochemical study has been completed on these groups of plants. This study complements the previous study on ferns, another class of ancient plants. There were two purposes for these studies: first, to investigate the distribution of biosynthetically-related compounds, hydrocarbons and fatty acids, to a series of related ancient plants, and second, to determine what chemical changes took place in the evolution of plants. This information aids both the botanist in classification of plants and the geochemist in identifying the source material from ancient environments; i.e., oil shales, petroleums and coal fields, and also elucidates the relationship between geolipids and biolipids.

Techniques Development for Oil Pollution Assessment (Funded in part by the Bureau of Land Management and GCRL): This study was designed to decide upon the best procedures to analyze natural samples when trying to detect oil pollution. Included in the study were various extraction procedures, separation procedures and various types of samples both polluted and nonpolluted. The results will be published and should help others in properly designing oil-pollution monitoring studies in the marine environment. Available techniques are numerous but an effort was needed to examine the various methods to determine procedures that would yield results most easily amenable to interpretations of oil pollution.

Sediment and Floral Hydrocarbons of the MAFLA Monitoring Program (Funded by Bureau of Land Management, U. S. Department of Interior–Conducted jointly with the Environmental Chemistry Section): An environmental study in the northeastern Gulf of Mexico has been underway since 1974. The broad objective of the study is to provide enough information about the area that will enable the BLM to answer questions about the impact of oil and gas exploration and development on the marine environment and to establish a basis for prediction of impact on the outer continental shelf oil and gas activities in frontier areas.

The Analytical and Environmental Chemistry sections were awarded the contract to analyze the hydrocarbons in

all sediment and benthic algae samples taken from selected sample sites in the northeastern Gulf.

The offshore oil leases in the northeastern Gulf of Mexico in 1974 have resulted in an extensive program of scientific activity on the continental shelf of Mississippi-Alabama-Florida (MAFLA). The 1974 program included a baseline hydrocarbon survey of sediments of the inner continental shelf extending from Tampa, Florida, to the Mississippi River delta. Though intended as an environmental impact study, the efforts of investigators in this region have complemented previous studies concentrated in the deep basin and estuarine systems of the eastern Gulf.

Results of the initial study disclosed two distinct hydrocarbon provinces in the northeastern Gulf. The Florida shelf, rich in carbonaceous materials, was characterized by very complex mixtures of hydrocarbons which were apparently of marine origin and were dominated by a group of C_{25} branched-unsaturated compounds. Sediments of the Mississippi and west Alabama shelf, chiefly comprised of silt and clay materials, yielded hydrocarbons with a very distinct terrestrial signature of high molecular weight *n*-alkanes of high odd/even preference. Also in evidence was a suite of petroleum-like hydrocarbons indicating a degree of pollution on the Mississippi-Alabama shelf. The east Alabama-west Florida shelf acted as a transition zone containing pronounced contributions of terrestrial, marine and petroleum hydrocarbons.

In 1975–76 the monitoring phase of the study expanded the 1974 sample program to include deep-water sites on the outer continental shelf, sites further south on the Florida shelf and collections made during more than one season to detect short-term or seasonal changes in hydrocarbon profiles.

Perhaps the most intriguing results found in the 1975 samples involve the outer continental shelf along the northeastern Gulf. Here sediments on the Florida coast lose some of the shell hash-sand appearance of inner shelf samples and are composed of higher quantities of fine-grained materials like those found along the Mississippi coast. Hydrocarbon levels are generally higher at the deeper stations than at the shallower stations. Some contribution of marine materials is evidenced by the presence of certain hydrocarbon compounds; but, what is surprising is the obvious presence of terrestrial and petroleum hydrocarbons at these deep-water stations. It appears that sediments of composition similar to those of the Mississippi shelf are being transported as far south as the outer shelf off Ft. Myers, Florida. If that is the source, then the migration of riverine sediments and any associated pollutants may be more extensive than was previously thought. Other tagging methods including carbon isotope ratios are being checked to verify the terrestrial component of these sediments.

There are some short-term effects seen in sediment hydrocarbon patterns of the northeastern Gulf. Only those stations exhibiting traces of petroleum-like hydrocarbons off the Mississippi-Alabama coastline reveal discernible change, that being a steady decrease in low molecular weight *n*-alkanes with time. Even in samples just east of the track of Hurricane Eloise (September 1975), temporal effects were of very small order.

Sediment and Floral Hydrocarbons of the MAFLA Rig Monitoring Program (Funded by Bureau of Land Management, U. S. Department of Interior–Conducted jointly with the Environmental Chemistry Section): In order to assess the changes in hydrocarbon concentrations and distributions in a marine sediment due to the emplacement and operation of an oil rig, sediment samples were collected from 25 strategic locations at a site on the Texas shelf before emplacement, during drilling and after drilling. These sediments were analyzed for aliphatic and aromatic hydrocarbons and 13 gas chromatographic parameters, used in assessing pollution, were calculated. A type of graphic cluster analysis was used to determine statistically changes in these 13 parameters as a function of distance from rig and collection period. We found that gas chromatographic parameters which have been developed to signal oil pollution must be treated cautiously; the natural variability can be quite large in some cases and therefore requires careful consideration of sample size for sediments used in pollution monitoring. Additional statistical techniques may be necessary in order to choose the proper sample size and replication.

This information has been needed so that BLM might be able to produce "benchmark" data which will be quantitative and for which statistical significance can be established. Statistical techniques such as cluster analysis and discriminant analysis that simultaneously assess several hydrocarbon parameters seem to show promise in the area of pollution monitoring. The hydrocarbon data have shown that at least this one part of the continental shelf of Texas appears to be the site of low-level oil pollution. The C_{14} to C_{20} region contained a series of *n*-alkanes with little odd/even preference and ratios of pristane/*n*-C_{17} and phytane/*n*-C_{18} similar to those of petroleum. The region of high molecular weight contained high concentrations of the odd carbon numbered *n*-alkanes with a predominance of *n*-C_{29}. A large concentration of two components in the aliphatic fraction is tentatively identified as branched-chain olefins, $C_{25}H_{46}$ and $C_{25}H_{48}$.

Even though the Texas sediments have accumulated relatively low concentrations of degraded oil, cluster analyses data show that there was little difference between samples taken before, during and after drilling even at sites only 100 m from the rig. It is concluded that exploratory oil drilling phases of offshore procedures can be achieved without radically altering the status of hydrocarbon levels and patterns of the surrounding sediments.

BOTANY SECTION, Dr. Lionel N. Eleuterius, Head

Studies of Plant Colonization on Dredge Spoil (Funded by GCRL): The study was initiated several years ago and will yield valuable information about natural colonization of spoil islands. Several spoil islands representing various ages have been monitored several times during each year to obtain information on what species colonize the spoil and what is the rate of vegetative spread. Other spoil areas are visited frequently. Botanical information is taken in reference to elevation, substrate type, soil water and soil-water salinity. Arrangements have been made with the Mississippi State Soil Testing Laboratory to analyze soil samples for levels of mineral nutrients. A cooperative effort with the Physical Oceanography Section is planned to provide tidal data.

Salt Marsh Vegetation of Davis Bay (Funded by GCRL): Quantitative information is being accumulated on the relationship of marsh acreage versus open water in this productive estuarine system. In addition, the total area drained and the amount of rainfall will be determined in order to study an entire estuarine ecosystem from the plant ecology viewpoint. A detailed vegetative map is being prepared as well as that of the standing crop of all marshes surrounding Davis Bay. This information is basic to further detailed botanical and ecological studies in the area around GCRL and should provide information for students, scientists and others within the State.

Populational Studies on Salt Marsh Species (Funded by GCRL): This on-going research is presently concentrated on the salt marsh rush, *Juncus roemerianus*. Considerable population information has been gathered on the species and a portion of it is now in manuscript form. The ultimate goal is to document the distribution and the vegetative growth pattern of the major salt marsh species inhabiting the tidal marshes in Mississippi. Such populational studies are of considerable importance in relation to ecological work since ecotypes, single sexes, may dominate or compose large tracts of tidal marsh. Similar work has been initiated on *Scirpus olneyi* and *Distichlis spicata*.

Ecological Studies on Seagrasses and Salt Marsh Species (Funded by GCRL): Survey work will be done during July, August, and September 1977 to assess the distribution of seagrasses in Mississippi Sound. In addition, quantitative information will be developed on the ecological aspects of the shoal grass, *Halodule beaudettei*.

Ecological studies on salt marsh species will entail synecological studies where more than one species compose the vegetation. Included in this study is consideration of the hydraulic aspects of flooding of various salt marsh zones to be done in cooperation with the Physical Oceanography Section. Grand Bayou, a high-salinity marsh dominated by *Juncus roemerianus* on Deer Island, Mississippi, has been tentatively selected for this portion of the study.

Studies of other ecological aspects of this tidal marsh have been initiated. Tidal inundation and discharge rates can be easily established because of the small, contained ecosystem represented in Grand Bayou. Quantitative data on plant productivity and the nutritive discharge of detritus and other water quality parameters will be assessed on the discharge and on the rising tide.

Autecological Studies on Vascular Plants of Mississippi Salt Marshes (Funded by GCRL): This project is essentially an extension of populational studies, in that ecological parameters such as soil nutrients, soil-water salinity, elevation, and other chemical and physical aspects of the habitats (i.e., soil texture, evaporation) and the life history of the plant will be considered.

Progeny and Genetic Studies on the Salt Marsh Rush, Juncus roemerianus (Funded by GCRL): This work entails on-going research representing work carried out over several previous years. Plants have been grown for several years from seed to obtain Mendelian ratios, establishing the genetic mechanism responsible for the sexual distribution found in this rush species. The work constitutes an effort to obtain basic information on this species which dominates Mississippi marshes. During the past year, controlled crosses between known parental types have been achieved and their seeds are presently being germinated. Hopefully, they will produce mature plants in less than the 2 years required under field conditions.

An apparatus has been constructed in the greenhouse that will extend or shorten the day to induce flowering. Also, experiments have been conducted dealing with the physiological requirement of a cold period, known as vernalization, to induce flowering in this rush. If flowering can be induced, the growth and flowering cycle can be accelerated.

An Illustrated Guide and Key to Salt Marsh Plants (Funded by Mississippi-Alabama Sea Grant Program): The purpose of this work is to prepare an illustrated guide and key to the salt marsh plants of Mississippi. It will entail the preparation of line drawings and scientific descriptions and a key to the local species. At present, approximately 140 species have been collected and will be included in the key. The key is expected to be completed by the end of next year.

A Phytosociological Study of Horn and Petit Bois Islands (Funded by National Park Service, U. S. Department of Interior): During the first year of this two-year study, a large number of exclosures were established to assess the effect of animals such as nutria, hogs, and rabbits on the vegetation. Concurrently, phytosociological sampling was initiated to obtain information on community composition and successional patterns and interrelationships between the plant communities on these islands. Considerable effort has been made to obtain information on insular marshes which

will be part of general ecological studies on salt marshes in Mississippi. A detailed report, pointing out the special features of these insular marshes, is in preparation.

ECOLOGY SECTION, Dr. Robert A. Woodmansee, Head

Baseline Environmental Survey of Plankton of the Mississippi-Alabama Continental Shelf (Funded by GCRL): This project is designed to acquire a data base for zooplankton and related environmental parameters for the continental shelf of Mississippi and Alabama, particularly in the oil lease sale area and at the proposed site of a deep-water port. Establishment of a baseline in these areas will make it possible to assess the impact of oil exploration and production or deep-water port activities on the continental shelf.

Daily Vertical Migration of Zooplankton in Relation to Light Intensity, Currents and Reproductive Cycles (Funded by GCRL): The daily vertical migration of zooplankton is of significance to the probable location of plankton-feeding fish and, thus, to the probable location of fish higher in the food chain. The interaction of vertical migrations, currents and reproductive cycles provide the means by which planktonic larvae of shrimp and other forms are able to move from the offshore spawning areas into the estuaries.

Benthic Infauna of a Residential Canal and an Adjacent Natural Area in Simmons Bayou (Funded by GCRL): The purposes of this study are: (1) to compare the relative abundance and composition of benthic macroinvertebrates in a residential canal with those of an adjacent natural bayou; (2) to relate invertebrate abundance and composition to selected environmental parameters; and (3) to provide baseline information which may aid in determining the effects of future environmental perturbations.

Gulf of Mexico Shrimp Management Plan (Funded by GCRL and National Marine Fisheries Service): The goal of this study is to develop a management plan for shrimp resources of the Gulf of Mexico that will provide optimum benefits for the Gulf states and the Nation. This project is in cooperation with and under the direction of the Fisheries Research and Development Section (see).

ENVIRONMENTAL CHEMISTRY SECTION, Dr. Julia S. Lytle, Head

Further Characterization of Fatty Acids and Hydrocarbons from Gulf Sediments (Funded by GCRL and Carnegie Geophysical Institute): Many hydrocarbon components isolated from Bureau of Land Management sediment samples were only identified by a Kovats Indices. In order to fully understand where these compounds originated, it was necessary to further characterize them. Because hydrocarbon concentration levels were extremely low in the northeastern Gulf, the original extracts were not sufficient to perform various chemical analyses. Therefore, permission was given to extract the 1974 archived sediment samples. By combining extracts from several similar sediments, we were able to collect enough for high pressure liquid chromatography separation. The olefinic fractions were separated from the saturated fractions using silver-nitrate impregnated silica gel adsorption chromatography. Various other separations allowed for cleaner gas chromatographic separations which were then identified by mass spectrometry. Information obtained from these characterizations has contributed to the understanding of the biogenesis of organic matter in marine environments.

Sediment Size and Hydrocarbon Associations (Funded by GCRL): To better understand transport of petroleum pollutants, it is important to know what fractions of the sediments (sands, silt, clay) the pollutants adsorb or chelate with most strongly. Several types of sediments were fractionated into sands, silts and clays, and each fraction analyzed for aliphatic and aromatic hydrocarbons. In all cases, the petroleum pollutants were associated almost entirely with the silts and clays. These fractions can get transported great distances from the original location of the spill or seep. These data correlate well with results of our BLM studies. The deepest BLM sediment samples along the Florida continental slope appeared to be polluted with low concentrations of petroleum like those from the Mississippi-Alabama coastline. At the same time, the sediments closer to the Florida shoreline were pristine. One could postulate using the results of this study, that the currents from the Gulf stream could carry the polluted clay-silt fraction from the Mississippi-Alabama coastline around the Gulf depositing it along the continental slope as far south as Ft. Myers, Florida.

Studies of Chemical Constituents of Mosses, Fungi and Lichens (Funded by GCRL): This project is an intersectional operation with the Analytical Chemistry Section (see).

Techniques Development for Oil Pollution Assessment (Funded by GCRL): This project is an intersectional operation with the Analytical Chemistry Section (see).

Mississippi Oil Field Study (Funded by GCRL): Sediment samples were collected from Grand Isle, Louisiana, along a 100-mile transect due south. This cruise was made available by the National Science Foundation on the research vessel LONGHORN from the University of Texas. Because the transect passed through active oil fields, this was an opportunity to analyze deep sediments most likely to be polluted with petroleum and to compare these samples with BLM sediment samples previously analyzed from a transect off Pascagoula, Mississippi. All sediments along the transect south of Grand Isle were highly contaminated with petroleum. The extent of pollution was on the order of ten times that of the sediments collected off of Pascagoula, Mississippi. This was not surprising since the Louisiana

coastline has long been an area of active oil drilling. This study documents hydrocarbon analyses in sediments along the Mississippi trough in the Gulf of Mexico.

Sediment and Floral Hydrocarbons of the MAFLA Rig Monitoring Program (Funded by Bureau of Land Management, U. S. Department of the Interior): This project is an intersectional operation with the Analytical Chemistry Section (see).

FISHERIES MANAGEMENT SECTION, Mr. William J. Demoran, Head

Oyster Atlas (Funded by GCRL): An updated survey of natural, public oyster reefs was undertaken during the period. An Atlas of the public reefs was furnished the Mississippi Marine Conservation Commission to be used in granting private oyster leases. The Commission is presently in the process of leasing water bottoms where public oyster reefs do not exist. The Atlas comprises three maps showing natural, public reefs.

Oyster Bottom Survey (Funded by GCRL): Potential oyster leases were examined in western Mississippi Sound to determine if any natural, public oyster reefs were included in the leases. Also, the bottom where leases were requested was examined for suitability. Under a new law, which gives the Mississippi Marine Conservation Commission additional power and authority for leasing water bottoms in the State, these two requirements must be fulfilled before a lease is granted.

Development of a Regional Fishery Management Plan for Gulf Menhaden (Funded by National Marine Fisheries Service): The section head, in collaboration with the Fisheries Research and Development Section, served as a member of the Menhaden Task Force which developed a regional management plan for the menhaden fishery of the Gulf of Mexico.

Environmental, Legal and Management Aspects of a Proposed Oyster Depuration Facility (Funded by Mississippi-Alabama Sea Grant Program): The success of any depuration operation depends on interagency cooperation among the many agencies concerned with the shellfishing industry. The section is in the process of contacting controlling agencies in states with existing depuration plants or which have operated plants in the past, to determine their management procedures. These will be compiled and utilized to develop a management plan for submission to state and federal agencies which must approve or cooperate in such an operation. Considerable input into this plan is expected from both state and federal levels. It is expected that the resulting management plan will detail the procedures governing harvesting of oysters from polluted waters and transportation of same to the depuration plant. The plan will also detail procedures for in-plant operation that will insure that oysters released from the plant for sale are safe for human consumption.

FISHERIES RESEARCH AND DEVELOPMENT SECTION, Mr. J. Y. Christmas, Head

Fishery Resources Monitoring and Assessment (Funded by National Marine Fisheries Service and GCRL): Three years of sampling in the original monitoring and assessment project were completed in September 1976. All stations were sampled every month. Analyses of the resultant massive data bank provided detailed information about relative abundance, life history, condition, survival and growth of important exploited species in Mississippi waters. Computer programs were refined for compiling and analyzing data.

A new three-year project was approved, effective 1 January 1977, to continue this program. Cooperative efforts to provide data leading to achievement of optimum yield from fishery resources are continuing. Appropriate segments of this work have been closely coordinated with NMFS's research in Gulf waters. Continuing liaison with the Mississippi Marine Conservation Commission (MMCC), Mississippi-Alabama Sea Grant Consortium, numerous other state and federal agencies and industry representatives have provided for a progressively improved scientific base for fishery management.

The Mississippi brown shrimp crop for 1977 was outstanding. The MMCC opened the Mississippi shrimp season in accordance with recommendations based on monitoring and assessment data collected for them. Catch data are not complete but preliminary estimates indicate a near-record volume and record value as indicated in monitoring and assessment data. White shrimp followed typical patterns of abundance with a good crop predicted for the fall harvest in 1977. Pink shrimp show increasing numbers from year to year with wider distribution observed during periods of unusually high salinity.

Blue crabs, after a period of relatively low population levels during part of the study period, showed a strong year class developing in the spring and early summer of 1977 and more crabs were available than processors could handle.

Finfish populations in general remained healthy with some annual fluctuations in response to changing environmental factors. Young-of-the-year croaker showed annual increases through the 1975–76 year class but smaller numbers appeared in the 1976–77 year class. Survival to recruitment in the offshore population seems to be lower than expected. Young-of-the-year speckled trout increased dramatically in the last two years. Good fishing from these year classes is expected to start next year.

Fisheries Planning (Funded by GCRL): Active participation in fishery planning activities of National Marine Fisheries Service, Gulf States Marine Fisheries Commission, the

Commission's Technical Coordinating Committee and subcommittees, Gulf State-Federal Fishery Management Board, Sea Grant Association, Mississippi Marine Resources Council, Mississippi Marine Conservation Commission, Gulf of Mexico Fisheries Management Council and several professional societies provided for effective input of Mississippi's position in practically all Gulf of Mexico fishery planning activities. Project personnel served as a member of the Mississippi Marine Conservation Commission.

Management plans for Gulf of Mexico menhaden and shrimp were completed after approval and adoption by the Gulf State-Federal Fisheries Management Board. The Gulf of Mexico Fisheries Management Council expressed an interest in coordination of Council plans for fishery management in the offshore Fisheries Conservation Zone with plans for regional management in State waters.

Statistics on Subsistence Fishing in Coastal Counties of Mississippi (Funded by National Marine Fisheries Service and GCRL): The manuscript comprising the completion report for this project reports new information acquired in the three-year study.

Mississippi Marine Conservation Commission requires licensing of all boats and vessels utilizing gear generally used by commercial fishermen. There are no provisions for licensing or regulating recreational fishing. Many licensees sell a small part or none of their catch. Additionally, commercial fishermen utilize a part of their catch for home use. That part of the catch of licensed fishermen which is not sold was designated as the subsistence catch. The subsistence catch is not reported in commercial fishery landings.

Catch and effort data for the subsistence fishery were collected from random samples of licensed commercial fishermen in open season during the 1974 to 1976 study period. Subsistence fishermen reported using shrimp, crabs and four species of finfish. The subsistence catch was equivalent to over 12 percent of reported landings of these species caught in Mississippi waters, to 3.7 percent of Mississippi landings of these species and had an annual dockside value of $180,000. Cost of expendables was estimated at $141,029 per year. Areal and seasonal distribution of catch and effort were discussed.

Development of a Regional Fishery Management Plan for Gulf Menhaden (Funded by National Marine Fisheries Service): "The Menhaden Fishery of the Gulf of Mexico United States: A Regional Management Plan" was published (May 1977) as Technical Report Series, No. 1, Gulf Coast Research Laboratory. The 53-page document was developed in a series of five open-meeting workshops utilizing "management by objectives" techniques.. The Gulf Menhaden Management Task Force was established when the Gulf State-Federal Fisheries Management Board approved a project proposal for development of a Gulf Menhaden Management Plan. Representatives of each of the five Gulf states fishery management agencies, the National Marine Fisheries Service, each of the five menhaden companies operating in the Gulf of Mexico and specialists from several universities contributed invaluable time to attending workshops and completing "homework" assignments.

The Plan document includes a summary, a description of the resource and fishery, present management system and associated problems, goal and objectives, proposed system, recommendations and a management action program summary in seven chapters. A discussion of planning methodology and chronology and a list of references cited (101) are appended.

The Task Force recognized 20 problems in the fishery and made 24 recommendations leading to solution of these problems. The dynamic nature of the plan was stressed and provision was made for regular reassessment and updating as necessary. This project was carried out as a cooperative effort between Gulf Coast Research Laboratory and the University of Southern Mississippi.

GEOLOGY SECTION, Dr. Ervin G. Otvos, Head

Offshore Barrier Island Study (Funded by GCRL): This was a study of the geologic history, genetic conditions and present-day state of six Mississippi-Alabama barrier islands. Seven coreholes were drilled on Ship Island and five on Horn Island in 1976, and drilling (three coreholes) on Petit Bois Island continued during June 1977. Sediment and micropaleontological analyses have been completed for samples obtained in 1976 on Horn and Ship Islands. Assistance in sea and land transportation was provided by the U. S. National Park Service. The Civil Air Patrol provided assistance with aerial photography of the islands.

Marsh Bottom Soil Sample Analysis Project (Funded by GCRL): The first stage of this work was completed in conjunction with the Botany Section. About 50 samples were analyzed to determine their granulometric composition. The correlation of soil properties thus obtained, with marsh vegetation characteristics, is expected to yield meaningful results.

Foraminifer Studies in Lake Pontchartrain and Adjacent Coastal Water Bodies, including Biloxi Bay-Biloxi Back Bay: Geological Evolution of Lake Pontchartrain (Funded by GCRL): The foraminifer composition of Lake Pontchartrain bottom deposits is quite unusual, as the oligohalin lake, with salinities commonly between 3 and 6 ppt, contains patches of calcareous-rich areas. Presettlement Pontchartrain deposits were also found with high-calcareous foraminifer-influxes. These contrast strongly with the Biloxi Bay fauna with usually higher salinities. Interpretation of the results sheds light on the Holocene recent geological history of the area. The results of this study will be reported in the *Journal of Foraminiferal Research.*

Holocene Geology of Hancock County Marshland (Funded by GCRL): The largest marshland on the Mississippi coast also contains large sand ridges and extensive prehistoric shell mounds. Earlier drilling results, field surveys and botanical surveys are being integrated into a report, presently in preparation, that will give an account of the Holocene evolution of the premarsh area, the marsh itself and various peculiarities of its present vegetation. The unusual plant assemblages covering Indian middens will be emphasized. This study is being done in conjunction with the Botany Section.

Mississippi Coast Stratigraphy and General Geology (Funded by GCRL): Studies of earlier-obtained cores continued in the sedimentation laboratory. This is part of an on-going study of the Pleistocene-Holocene evolution of the entire coast. Several field trips and collections supplemented the core studies, especially in the Hancock County area where the Biloxi and Prairie Formations have been investigated.

Pleistocene Geological Evolution of Southeastern Louisiana (Funded by GCRL): Areas adjoining the Mississippi Gulf Coastal Plain contain significant proof of the time the surficial sediments of the plain complex evolved. The problem of a mid-Wisconsin interstate, a period of relatively warmer climate and higher sea level stand might be more closely approached by the study of river terrace sediments in the St. Francisville area and near Slidell, both in Louisiana. The terrace stratigraphy of this area has an immediate impact on the various stages of the Pleistocene evolution of the coast. Field work and radiocarbon age determinations have proceeded.

Chenier Genesis and Nomenclature in the U. S. A. and Worldwide (Funded by GCRL): Cheniers are rare and peculiar coastal ridge systems, found also in the north-central Gulf coastal plain. An effort is being made to clarify problems in the literature relating to nomenclature and to classify these features. Work done in the Hancock County marsh area, especially drilling results, will be incorporated in this project. This study is being done with the collaboration of W. A. Price, Corpus Christi, Texas.

The Bartram Trail, National Heritage Land Trust Program (Funded by GCRL): The Mississippi Bureau of Outdoor Recreation requested the Geology Section to supply data and recommend locations for the Mississippi sections of a national system of William Bartram Trails (a bicentennial national project). The locations to be developed are in the area of the five coastal counties. The sites would be of unusual geological, geographical and general interest.

MICROBIOLOGY SECTION, Dr. David W. Cook, Head

A Study of the Genus Bacillus in Marine and Estuarine Sediments (Funded by GCRL): The distribution, taxonomy and ecology of the genus *Bacillus* in the estuarine environment is being investigated. Under intense study this year has been a newly isolated and previously undescribed strain of *Bacillus cereus* which produces orange pigmented asporogenous mutants. Pigmentation in the mutants is affected by the metal ions present in the seawater component of the culture medium.

Bacteriology of the Blue Crab Industry in Mississippi (Funded by GCRL): Both research and service are the thrust of this project. Research is being conducted into the bacteriology of blue crab meat spoilage with the emphasis on determining if spoilage is brought on by a specific kind of bacteria. The service phase of this project is dealt with under Special and Community Services.

Persistence and Degradation of Insecticides in Estuarine Water and Sediment (Funded by GCRL): This project is one of a continuing nature and involves the persistence and/or degradation of organophosphorus and chlorinated hydrocarbon insecticides in the estuarine environment. Both chemical and biological (especially microbiological) degradation are of concern, as are the various by-products resultant from the breakdown of these materials. Insecticides studied to date include malathion, parathion, methyl parathion, diazinon, and mirex. Two bacteria capable of metabolizing methyl parathion have been isolated into pure culture, but neither microbial or chemical degradation of mirex has been demonstrated.

Insecticide Persistence in Natural Seawater as Affected by Salinity, Temperature, and Sterility (Funded by U. S. Environmental Protection Agency): The objective of this research effort was to determine the effect of temperature, salinity, and sterility on the persistence of malathion, parathion, methyl parathion, diazinon, and methoxychlor in natural seawater. Three temperatures (10°, 20° and 30°C) and four salinities (1, 10, 20 and 28 ppt) were employed in these investigations. Sterile and nonsterile treatments were included for each temperature and salinity.

This project was concluded and the final report is currently in preparation, but the data indicate that the disappearance of malathion, parathion, methyl parathion, and diazinon increased with increasing temperature, increased with increasing salinity, and was not affected by sterility. No degradation of methoxychlor was observed under any of the test conditions employed herein. Two bacteria capable of degrading methyl parathion and two capable of degrading diazinon were isolated into pure culture.

Acute Toxicity of 3-Chloro-4-Methyl Benzomine Hydrochloride to Shrimp and Crabs (Funded by U. S. Department of the Interior, Fish and Wildlife Service): A total of 150 penaeid shrimp and 225 blue crabs were exposed to 3-chloro-4-methyl benzamine hydrochloride (starlicide) for 96 hours under standard, static, bioassay conditions. Starlicide concentrations for shrimp were 50, 25, 10, 1.0, 0.1, and

zero ppm (μg/g) and 50, 25, 20, 15, 10, 1.0, 0.1, and zero ppm for crabs. Symptoms of death were lack of gill movement and particularly no response to touching with a glass rod. Regression analysis was employed to analyze the data, producing a calculable TLM (or LD_{50}) of 10,789 ppm for shrimp and 15,991 ppm for crabs.

The Determination of the Acute Toxicity of Dredged Material to Fish and Macroinvertebrates under Standard, Static, Bioassay Conditions (Funded by GCRL): Surface sediment (0–4 inches) was collected both from the inner harbor and the approach channel at the Broadwater Beach Marina in Biloxi, Mississippi. These sediment samples were then processed in accordance with U. S. Environmental Protection Agency guidelines and utilized as toxicants to blue crabs and mysid shrimp under standard, static, 96-hour, bioassay conditions. No deaths were observed with the blue crab, while shrimp deaths were at random and not associated with sediment concentration. Similar studies involving penaeid shrimp and sheepshead minnows are currently in progress.

St. Louis Bay – Effluent Toxicity Evaluations (Funded by E. I. duPont de Nemours & Company): The toxicity of a simulated industrial waste discharge to penaeid shrimp, blue crabs, oysters, sheepshead minnows, and mosquitofish has been determined under standard, static, 96-hour bioassay conditions. The effluent utilized in these investigations was prepared in accordance with the maximum daily averages listed on page 2 of 14 of permit No. MS 0027294, Mississippi Air and Water Pollution Control Commission. Effluent concentrations employed were 50, 35, 20, 10, 1, and zero percent.

No mortalities were observed in crabs, oysters, sheepshead minnows, or mosquitofish, during the 96-hour test period. A calculable LD_{50} value of 36.36 percent was obtained for shrimp, a level that is clearly unrealistic in the natural environment. Additional investigations with penaeid shrimp are currently in progress.

Evaluation of Methods for Long Term Freezer Storage of Blue Crab for Use in Picking Plants (Funded by Mississippi Marine Resources Council): Live crabs are being processed by two methods prior to freezing and storage to determine if either method is suitable for long term storage of frozen crabs for later use. When the crabs are removed from storage they are further processed and picked. Crabmeat from both processes is being compared with unfrozen crabs for organoleptic acceptability, pickability, bacteriology and storage life.

MICROSCOPY SECTION, Dr. Harold D. Howse, Head

Morphological Study of the Brown Shrimp Gill (Funded by GCRL): This study utilized the transmission electron microscope to examine the structure of the brown shrimp gill and to characterize the various cell types. As outgrowths of the body wall, each gill (19 pairs total) is covered by a cuticle which is periodically shed during molt. The epithelium underlying the cuticle is adapted not only for efficient respiration, but also for cuticle secretion and osmoregulation. The gill is innervated, is vascularized with blood sinusoids and vessels, and has an extensive internal defense system of free and fixed phagocytes. The results of this study provide a basis for future applied research to assess the effects of pathological agents and environmental stresses upon the gill.

Effects of Cadmium on Teleost Gills (Funded by GCRL and the University of South Alabama School of Medicine, Mobile): This study was initiated, in collaboration with the University of South Alabama School of Medicine, to study the gills of spot *(Leiostomus xanthurus)* that were exposed to various concentrations of cadmium and to determine morphological changes that might result from exposure to this heavy metal.

Ultrastructure of Lymphocystis in the Heart of the Silver Perch, Bairdiella chrysura (Lacépède), including Observations on Normal Heart Structure (Funded by GCRL): This study was completed and revealed that the fine structure of normal heart muscle from the silver perch, *Bairdiella chrysura* (Lacépède), is similar to that previously reported for marine and freshwater teleosts.

Cardiac lymphocystis is a viral disease manifested by single, giant-cell lesions variously located in the epicardium, trabecular spaces, and subendocardium—in direct apposition to myocardial cells. Occasionally, the hyaline capsule of lymphocystis cells partially surrounds myocardial cells but causes no pathological changes or inflammatory reaction.

The lymphocystis cells contain typical cellular organelles, including the viroplasmic net unique for these cells. Annulate lamellae, often continuous with the rough endoplasmic reticulum, are present, usually along the periphery of the cell. Some elements of the rough endoplasmic reticulum are dilated and contain a finely granular material, but others contain cross-banded fibrils, each having a periodicity of 30 nm. Similar fibrils are present in the perinuclear cisternae.

OYSTER BIOLOGY SECTION, Dr. Edwin W. Cake, Jr., Head

Oyster Spat Monitoring Program (Funded by GCRL): This project is concerned with the time and intensity of setting of oyster "spat" in various areas of Mississippi Sound and on two barrier islands. It also includes elucidation of major fouling organisms such as barnacles and their seasonality.

Plankton Samples (Funded by GCRL): A program to monitor the number of bivalve larvae in bay water was initiated in May 1976 at the Oyster Hatchery, Point Cadet, Biloxi, to serve as an index of spawning activity in local

oysters. Results of samples generally correlate with the spat set observed on asbestos fouling plates. It is hoped that this will become a useful tool for the Mississippi oyster industry in predicting the best time for planting cultch material to maximize spat set. This method has been used in other oyster growing areas and has proven to be generally reliable.

Oyster Growth and Mortality Study (Funded by GCRL): Several locations in Mississippi Sound and adjacent waters were chosen for this study to compare the rate of growth and mortality of various oyster "seed" types, including hatchery-reared stock. Preliminary data indicate that oysters placed in a lagoon on an offshore island have significantly higher growth rates than those at other locations. Concurrent histological studies provide data on gonadal maturation of oysters at the different stations.

Biological and Ecological Studies of the Oyster Boring Clam (Funded by GCRL): The life cycle of this clam has been documented; its burrowing mechanisms have been examined. Data on distribution and population dynamics of boring clams in Mississippi Sound have been expanded. Research continues on the reproductive biology including the gonadal cycle and natural setting periods. Morphological studies on the adult clams are also in progress.

Gametogenesis and Spawning of the Mississippi Sound Oysters (Funded by GCRL): Monthly and bimonthly gonad samples from oysters collected in the western portion of the Mississippi Sound have been preserved and examined to determine the effects of temperature and salinity on annual spawning cycles. This two-year study will be completed by December 1977.

Black Drum Predation on Oysters and Other Invertebrates (Funded by GCRL): This study has produced the first documentation of the predatory behavior and predation rates for this little known species. Results suggest that large black drum may be the most destructive oyster predators in the Mississippi Sound.

Colonization and Growth of Benthic Invertebrates on Artificial Reef Structures (Liberty Ships) in the Northern Gulf of Mexico (Funded by GCRL): This multi-pronged study has documented the invertebrate faunal succession on new artificial reef structures. Organisms studied include hydroids, polychaetes, and amphipods.

Oyster Depuration in Mississippi: Environmental, Legal and Management Assessments (Funded by Mississippi-Alabama Sea Grant Program): This one-year study is the first of a three-year project that will prepare the state and oyster industry for eventual onshore depuration requirements of the U. S. Food and Drug Administration.

Free-Living Marine Invertebrates of Mississippi Sound and Adjacent Waters: A Summer Monitoring Program (Funded by GCRL): This student-oriented monitoring program seeks to further our knowledge of the major invertebrate assemblages present in Mississippi Sound and adjacent waters.

PARASITOLOGY SECTION, Dr. Robin M. Overstreet, Head

Parasites of Commercially Important Fishes (Funded by National Marine Fisheries Service and GCRL): This project primarily concerns the use of parasites to indicate migratory and feeding behavior of the Atlantic croaker. Feeding habits of several other local finfishes are also being investigated by analyzing stomach contents. The project additionally covers aspects of the effects of selected parasites on their respective hosts.

Parasites of Marine Animals in the Northern Gulf of Mexico (Funded by Mississippi-Alabama Sea Grant Program and GCRL): This project is divided into studies dealing with parasites infecting finfishes and shellfishes of commercial interest and those capable of infecting or causing disease in man. The latter studies predominantly include those concerned with parasites that can infect or cause disease in man if infected hosts are eaten raw or inadequately prepared.

Handbook of Marine Parasites of the Northern Gulf of Mexico (Funded by Mississippi-Alabama Sea Grant Program and GCRL): This project was established January 1977 to provide an illustrated handbook for the layman to help him understand some common parasites he is likely to encounter in finfishes and shellfishes.

Gulf Coast Survey of Fish and Shellfish for Parasites Pathogenic to the Human Consumer (Funded by Food and Drug Administration, U. S. Department of Health, Education, and Welfare): The purpose of the project is to survey four finfish and four shellfish seasonally from Mississippi, Texas (Galveston), and Florida (Tampa) for ascaridoids, heterophyids, and other parasites of public health importance. Representatives of those parasites found are fed to mice and to other mammals to determine their ability to live in or cause pathological changes in the hosts.

A Study of the Diseases of Fish of Mariculture Potential: Parasites and Parasite-Borne Diseases of Red Sea Mullets (Mugilidae) (Funded by the United States-Israel Binational Science Foundation): Because Mediterranean mullets have been maintained successfully in ponds and because disease in those fish is a serious problem, the diseases of Red Sea mullets were studied so as to judge the potential of those fish in culture. Emphasis also centered around heterophyid infections, since these trematodes can be transmitted to man.

Studies on Helminths of the Northern Gulf of Mexico Region (Funded by GCRL): A determination of parasites of hosts involved in the above projects as well as other hosts is included in this study. This includes life histories of the parasites and the relationships between parasites and hosts.

PHYSICAL OCEANOGRAPHY SECTION, Mr. Charles K. Eleuterius, Head

Hydrography of Mississippi Sound (Funded by Mississippi-Alabama Sea Grant Program): This was the last year of a

multi-year investigation of the hydrography of Mississippi Sound in which flow patterns, water structure characteristics and temporal and spatial distribution of nutrients were studied. The information obtained on the circulation and character of these estuarine waters is essential to the intelligent planning for Mississippi's coastal development, marine resources, maritime commerce and other marine-dependent industries. Because of the scope and intensity of work, results of the study are being published in a series of reports and technical papers.

Wave Refraction Analysis (Funded by Mississippi-Alabama Sea Grant Program): Loss of life and erosion of valuable waterfront property have been attributable to an adverse wave climate in Mississippi Sound and on the seaward side of the barrier islands. Applying a computer wave-refraction model, utilizing linear-wave theory, to a uniform bathymetric grid of the study area generates refraction diagrams. These diagrams, when interpreted, will show the locations of high energy areas and wave caustics under varying wave climates. The information will be useful in marine navigation, especially to the inexperienced boat operator, and to land owners and engineers in employing methods to prevent further erosion of waterfront property.

Characterization of Tidal Bayou and Development of Statistical Evaluation/Monitoring Techniques (Funded by GCRL): This is a continuing study of a critical area of estuarine systems, the contributary—especially the tidal bayou. Data to ascertain the most useful parametric statistics to characterize the system have been collected for the past three years. In addition to establishing baseline statistics, statistical techniques are being developed for monitoring the bayous for changes that might ordinarily go unnoticed.

Hydrography of Petit Bois Pass Area of Mississippi Sound (Funded by Mississippi-Alabama Sea Grant Program and GCRL): The water characteristics, flow patterns, temporal and spatial distribution of nutrients, water temperature and salinity of this segment of Mississippi Sound were studied. Information on the area, one of the two large nursery areas in Mississippi and Alabama remaining in near-pristine condition, was practically nonexistent prior to this investigation. The information gained through this research effort provides not only baseline data but also an insight into the dynamics present. Used by the proper agencies, this knowledge could help prevent unwise alterations to the area which makes a substantial contribution to the Mississippi and Alabama fisheries.

Air-Sea Heat Flux (Funded by GCRL): Water temperature is an important factor in the growth and migration of marine species. Attempting to forecast an opening date for shrimping season based on a statistical shrimp size is hampered by the variability in growth rate which is dependent, in part, on the temperature of the water. This study includes the development of a predictive, stochastic model of heat flux in Mississippi Sound which will provide a means of predicting the thermal structure of the water column when given a set of initial conditions.

PHYSIOLOGY SECTION, Dr. A. Venkataramiah, Head

Studies on the Time Course of Salinity and Temperature Acclimation in the Commercial Brown Shrimp Penaeus aztecus Ives (Funded by U. S. Army Corps of Engineers): The interim report of this project (1973–1976) was submitted to the U. S. Army Corps of Engineers in August 1976 and was approved in December 1976. The revised final report submitted in February 1977 is presently in press at the U. S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi.

Some of the important findings of this study were: (a) juvenile brown shrimp (95 mm mean length) transferred directly from a control salinity of 15 °/₀₀ were apparently acclimated to a 10 to 25 °/₀₀ range within a day and to a 2 to 36 °/₀₀ range within a week at 25°C; (b) the ranges of salinity acclimation that occurred within one and seven days decreased to 10 to 25 °/₀₀ and 5 to 25 °/₀₀, respectively, when temperatures were changed to 18°C or 32°C; (c) between the two extreme temperatures, adjustment to salinity changes was more favorable in cooler (18°C) rather than in warmer (32°C) temperatures; (d) in contrast to the widely accepted conclusions, discrepancies were found between the respiratory and blood osmoregulatory patterns in the time course of acclimation process as a result of temperature change from 25°C. On this basis, the implications were discussed of accepting oxygen consumption as an exclusive criterion for the state of acclimation. Salinity and temperature optima were shown to vary in relation to the size (age) of brown shrimp, and physiological and behavioral responses were not significantly affected due to minor changes in the ionic ratios of Na^+, K^+, Ca^{++} and Mg^{++} of the holding medium. However, major ionic changes have produced physical abnormalities and high mortality, particularly in 18°C and 32°C conditions.

Evaluation of the Nutritive Value of Grass from High Marsh Areas for Brown Shrimp Penaeus aztecus Ives (Funded by Mississippi Marine Resources Council): Experimental work and data analyses of this project were completed and the final report was submitted in August 1977. The studies were undertaken to determine the feasibility of utilizing the marsh grass *Spartina patens*, and shrimp waste from the canning industry as a source of nutrition in shrimp culture. The rough consistency of the grass, low protein content (4 percent) and lack of acceptance by shrimp as food seem to rule out such a possibility. The juvenile shrimp have shown a tendency to utilize the decomposed grass as a protective covering rather than as food. The shrimp have exhibited a relatively better preference toward the grass pellets bound

with fish concentrate as an attractant, although growth and survival with the pellets are not significantly higher. However, the supplementation of shrimp waste evidently improves the survival and growth.

Studies on the Molting Frequency of Postlarval Brown Shrimp Penaeus aztecus Ives in Relation to Salinity (Funded by GCRL): The tentative conclusions from this study are that test salinities 5, 10, 15, 25 and 35 $^{o}/_{oo}$ have shown no significant effect on the molting frequency of postlarval shrimp. Size, however, has some effect on the molting frequency. Postlarvae in the initial length range of 9–12 mm and weighing less than 40 mg per animal molted every three or four days. Those in the initial length range of 10–15 mm and heavier than 60 mg per animal molted at an average of five days within a three-to-seven-day range. Larger postlarvae of 18–22 mm molted every five or six days.

Development of Penaeid Shrimp Larviculture for Use as Laboratory Animals (Funded by GCRL): The ready availability of shrimp postlarvae in the late 1960s and early 70s from several agencies along the Gulf of Mexico and southern Atlantic coast did not create any need for developing our own larviculture techniques. As a matter of fact, this facility saved us considerable manpower, laboratory space and other problems.

The postlarval supply has decreased in recent years either because of a shift in the research interests of the above laboratories from penaeid shrimp, or due to a reduction in the larviculture operations for budgetary reasons. This forced dependency on nature for postlarvae is strictly a seasonal affair. The development of larviculture at this laboratory will not only eliminate dependency on nature but will also provide laboratory-raised animals of known history on a year-round basis.

Determination of Calcium Levels in Blood, Muscles and Exoskeleton of Brown Shrimp Raised on Calcium-Deficient Diets (Funded by GCRL): While evaluating the nutritive value of marsh grass it was found that exoskeletons in a large number of shrimp raised on pure grass were either extremely soft or were of less-than-normal hardness, possibly due to lack of adequate calcification. The absence of soft exoskeletons in shrimp which received the control diet indicates that food is possibly their major source of calcium ions. These findings seem to be important in formulating shrimp diets used under controlled conditions. In view of this, further experiments will be conducted to monitor the calcium levels in blood, muscles and exoskeleton of shrimp provided with diets consisting of different levels of calcium salt.

Effect of Starvation on Blood Osmoregulation and Oxygen Consumption of Penaeus aztecus Ives (Funded by GCRL): "Standard Metabolic Rates" are measured ideally under the simplest and least physiologically demanding conditions by starving the test animals. Starvation is known to influence the oxygen consumption rates significantly in crabs and to deplete the energy reserves in blood, muscles and liver in fishes. However, the effect of starvation is little understood on the osmoregulation in brown shrimp, particularly in view of the fact that food is a possible major source of calcium. As such it is necessary to know how starvation of the test animals would affect the osmoregulation. Also it is important to know whether there is any significant correlation between the osmoregulatory and respiratory responses under starvation.

Effect of Temperature Changes on the Lethal Dissolved Oxygen Levels in Penaeus aztecus Ives (Funded by GCRL): Hypoxia is one of the major causes of heavy mortality in mariculture ponds. In comparison to fishes, very little is known about the lethal dissolved oxygen (LDO) levels in the crustaceans of commercial importance. The LDO levels of brown shrimp have been determined earlier at this laboratory in relation to size and salinity changes. Evidently temperature is an even more important factor in shallow-water habitats because of its influence on the saturation of oxygen and on the respiratory rates of estuarine animals. Our preliminary studies on temperature effect have shown that: (a) with a decrease in temperature from 32°C to 18°C, brown shrimp survived at decreased LDO levels, (b) female shrimp died at relatively higher LDO levels than males, and (c) the survival time in hypoxia increased significantly with decreasing water temperatures.

Biochemical Analyses of the Stomach Contents of Brown Shrimp during their Estuarine and Oceanic Life Phases (Funded by GCRL): Reports from our laboratory and from others have indicated that brown shrimp cease to grow to adulthood under laboratory conditions beyond the subadult stage of 125 mm mean length. Indeed, growth did not occur beyond this length even after 18 months of holding. In nature the shrimp become adults, mature and spawn in offshore waters. Some workers attempted to bring the shrimp to maturity under laboratory conditions by simulating some of the oceanic conditions in relation to pressure, salinity, pH and different wavelengths of light. However, none of these studies have yielded the desired results. In light of this background, analysis of the biochemical composition is planned of the food contents of juvenile and adult shrimp during estuarine and oceanic phases, respectively. On the basis of this information, attempts will be made to formulate food pellets by approximating the above compositions and for testing in the raising of shrimp.

SYSTEMATIC ZOOLOGY SECTION, Mr. C. E. Dawson, Head

Systematic Studies on Various Groups within the Families Gobiidae, Microdesmidae, Dactyloscopidae and Syngnathidae (Funded by National Science Foundation and GCRL): Work

was conducted on an undescribed species of the goby genus *Quisquilius* from the Ascension Island collection. Exhaustive studies on the pipefish genus *Hippichthys* and *Ichthyocampus* were completed and work was initiated on the genus *Penetopteryx* (and relatives), *Oostethus* and *Bhanotia*. Large amounts of data were accumulated in connection with the review of western Atlantic sand stargazers (Dactyloscopidae). Work continued leading to the review of western Atlantic pipefishes and on the distribution of tropical American shore fishes. In pursuance of these problems, studies were conducted on fishes at the following museums: Museum National d'Histoire Naturelle, Paris; Rijksmuseum van Natuurlijke Historie, Leiden; British Museum (Natural History), London; American Museum of Natural History; Peabody Museum; Museum of Comparative Zoology; Field Museum of Natural History; Rosensteil School of Marine Sciences; U. S. National Museum.

SPECIAL FACILITIES

MARINE EDUCATION CENTER, Mr. Gerald C. Corcoran, Curator

Visitations to the Marine Education Center increased from 19,675 in FY 76 to 23,844 in FY 77. Distribution of an informative leaflet to the local hotels and motels along the beach and also distributed by the Sea Grant Advisory service is credited with part of this increase, as well as tourists to the area.

The marine science courses for teachers that are taught at the Center had an enrollment of sixty-nine students—fifty-six in the basic course and thirteen in the advanced course.

With the cooperation of biology teachers from Gulfport and Biloxi High Schools, an outstanding student from each school is selected to further their studies at the Marine Education Center concerning local marine life. Informal instruction, along with practical experience, is given these students for approximately three months. At the end of that time two new students are selected to participate in this marine life enrichment program. It is hoped that all coastal high schools will participate and, in the near future, schools throughout the state will be able to enter students during summer vacation.

The Center prepared three slide sets concerning local flora and fauna; three sets of slides to aid in the identification of local poisonous and nonpoisonous species to present to the local school systems. Film strips available with recorded tape cassettes on the above subjects will be available in the near future.

Educational leaflets have been prepared on the horseshoe crab and the speckled trout and are now being distributed at the Center.

OYSTERY HATCHERY

The Oyster Biology Section continued research and development activities at the Oyster Hatchery in 1976. These activities included, but were not limited to the following: algal culture experiments (for larval and adult oyster food), experimental conditioning of mature oysters for out-of-season spawning, determination of the effects of vertebrate and invertebrate predators on seed oysters, design and testing of greenhouse and raceway culture systems for adult and seed oysters, and operational testing and maintenance of various hatchery systems. Hatchery-reared seed oysters have been provided to researchers in Mississippi and adjacent states for cooperative field and laboratory testing and mariculture attempts.

The enactment of Mississippi's Oyster Leasing and Relaying Law of 1977 has eased the requirement for hatchery-reared seed oysters, but not the requirement for additional knowledge and understanding of oyster spawning and settling cycles in Mississippi Sound. Hatchery personnel monitor larval oyster populations in plankton on a regular basis to assist those who wish to plant cultch material for natural spat-collecting purposes. Hatchery research on the effects of predators on attached and unattached (cultch-free) seed oysters will provide information on which cultch materials are best suited for maximum production of natural seed on leased oyster grounds.

The Oyster Hatchery has become one of the primary educational facilities of its type in the Gulf of Mexico region. Students and private individuals from many states and foreign countries have visited the hatchery and/or enrolled in the aquaculture course taught there during the Summer Academic Program. Those students enrolled for the past three years have received on-the-job training in oyster culture techniques and have conducted research on various aspects of aquaculture using the hatchery's facilities and systems. Many of those students are now pursuing graduate degrees and/or aquaculture-related vocations as a direct result of their training and experiences at the hatchery. Hatchery-reared seed osyters are presently being utilized by one Ph.D. candidate to assess the potential of intensive oyster culture in various parts of Mississippi Sound and adjacent waters. Results to date indicate that protected bayous on Mississippi's offshore islands offer the best potential areas for intensive oyster culture.

The hatchery's potential as an educational and research facility has been demonstrated and its contributions to marine science and to the Mississippi oyster industry should continue to increase and expand in the years ahead.

THE GUNTER LIBRARY, Mr. Malcolm S. Ware, Senior Librarian

The Gunter Library received about 2,000 publications in the form of reprints and separates from more than 250

research centers around the world through exchange. Book purchases amounted to 260 volumes; three new titles were added to the regular standing orders (250 titles), and back runs of journals were purchased with Special Library Improvement Funds to augment 32 journal titles.

A number of donations were received throughout the year; the most significant single donation was a master file of publications donated by the Mississippi-Alabama Sea Grant Consortium, which also pledged continuing monthly donations of reprints. Drs. John E. and Eleanor J. Tobie of the National Institutes of Health, and Dr. J. W. Ward of the University of Mississippi Medical Center donated lengthy runs of journals. Mr. Charles Lyles of the Gulf States Marine Fisheries Commission and Dr. Peter A. Isaacson of the State of New York Department of Public Service contributed publications in quantity. Mr. and Mrs. Wade Guice of the Harrison County Civil Defense Office and the Library of the University of Mississippi Medical Center were among the donors. The Gunter Reprint Special Collection continued to grow through the kindness of Dr. Gordon Gunter, Director Emeritus, GCRL.

The Dauphin Island Sea Laboratory Library and The Gunter Library exchanged duplicate journals which added qualitatively to both collections. Interlibrary loans sent out numbered around 100 items and loans received exceeded 375. The ratio of items borrowed to items loaned is statistically 4 to 1 because the figures necessarily include photocopy requests and do not reflect the fact that The Gunter Library actually served a larger number of libraries throughout the state than any previous year.

In July 1976, Miss Mary Lou Thornton of McComb, Mississippi, a senior in Library Science at the University of Southern Mississippi, completed her internship with the Library.

From August 1976 through January 1977, the Library cooperated in a continuing loan program to provide GeoMarine, Inc. of Richardson, Texas, with literature for the completion of a Biloxi River study.

In October 1976, The Gunter Library joined the majority of medical libraries on the Mississippi coast in forming the Gulf Coast Biomedical Library Consortium. The Consortium is dedicated to sharing resources, services, and programs to improve overall library service and meet its members' needs for biomedical information. The Gunter Library has been selected to act as a clearinghouse for inquiries and information concerning the Consortium.

ICHTHYOLOGY RESEARCH MUSEUM, Mr. C. E. Dawson, Head

The Museum, part of the Systematic Zoology Section, collected specimens in Panama and Venezuela during February 1977. The Panama work was conducted in cooperation with the Smithsonian Institution.

Eight hundred ten lots of fishes, representing about 6,000 specimens were cataloged. Total vertebrate holdings now include 15,704 cataloged lots; approximately 146,000 specimens. The collections also contain 1,074 cataloged lots of invertebrates.

An important collection of fishes from Ascension Island was received from The Division of Marine Invertebrates, U. S. National Museum. Gifts of specimens were also received from the University of South Alabama; Louisiana Department of Wildlife and Fisheries; Rosenstiel School of Marine Sciences; Rijksmuseum van Natuurlijke Historie; Museum of Zoology, Lisbon; Australian Museum; Western Australian Museum and H. I. H. The Crown Prince of Japan.

Loans of specimens were made to a number of U. S. and foreign institutions. Materials for identification were received from a number of U. S. sources as well as from Panama, Venezuela, Brazil, Colombia, Australia, France and Mexico.

WATER ANALYSIS LABORATORY, Dr. Thomas F. Lytle, Head

Operated by the Analytical Chemistry Section, the Water Analysis Laboratory has processed samples for the Physical Oceanography, Physiology, Microbiology, Ecology, Botany and Fisheries Sections. Sample types have been water, media, marsh plants and sediments. The analyses conducted have included: nitrate, nitrite, ammonia, Kjeldahl nitrogen, orthophosphate, total phosphorus, salinity, dissolved oxygen, sulfate, suspended solids, chlorophyll, phaeophytin, sodium, magnesium, iron, potassium, calcium, zinc and copper. These have resulted in 3,432 sample analyses. The Water Analysis Lab has also served in an advisory capacity to various staff members in planning sampling programs and has on numerous occasions helped people in the private sector with information on analytical problems.

COMPUTER SECTION, Mr. David Boyes, Head

Work began on several data retrieval systems, multidimensional statistical analysis programs, and higher forms of graphical routines. The training program for section personnel has resulted in an increase of machine time required for data processed and a reduction in time required to bring a program from planning to production stage.

Final equipment and programs were acquired for the tie-in of the Laboratory's IBM–1130 computer system with the Xerox Sigma IX system at the University of Southern Mississippi, Hattiesburg. The tie-in should be completed by early fall of 1977.

PUBLIC INFORMATION/PUBLICATIONS SECTION, Miss Catherine Campbell, Head

News releases on a variety of newsworthy subjects were provided to 50 selected daily and weekly newspapers,

television and radio stations, wire services and special correspondents.

Briefings on the research and academic programs and guided tours of the facilities were given to an average of one junior and senior high school science class per week during the regular school year. Briefings and guided tours are provided by the Section to summer students and by the Administrative Officer to college field trip students throughout the school year.

Duplicate sets of colored slides were made for a descriptive program on the Laboratory, and programs on two types of seafood processing. These programs were furnished to the public on request. A printed narration sheet and also a taped narration on cassette are available.

The Section provided participation by GCRL in three exhibits or public events during the year. An exhibit booth was set up during the Harrison County Community Fair on the Coast, sponsored by the MSU Extension Service. It featured the Laboratory and seafood industry slide programs and a display of GCRL and other publications on marine life. The Marine Education Center personnel set up two aquaria in the booth, one with a live horseshoe crab from salt water and a freshwater amphiuma. *Marine Educational Leaflets, Marine Briefs,* brochures on the MEC and GCRL and sheets telling how to prepare and serve shark dishes were handed out to the public. The Section set up a Laboratory literature display including scientific journals and curriculum information during the Academy of Sciences annual meeting in March. For the Mississippi Arts Festival in Jackson, the Section added to the display of marine specimens and staff publications located in the Mississippi Museum of Natural Science. At the request of the museum, a special program of 140 colored slides of marine life and a 45-minute narration on cassette were also furnished to be used by the Museum staff during the Festival.

The Laboratory's public information program "On Course," continued to be broadcast weekly by six coastal radio stations, WLOX and WVMI of Biloxi, WPMP and WKKY of Pascagoula, WOSM of Ocean Springs, and WPUP of Bay St. Louis. In addition, WSLI of Jackson and WJDQ and WDAL of Meridian began carrying the program.

Volume 5, Number 2 of the Laboratory journal, *Gulf Research Reports,* was published in December 1976. This number contained five papers and two short communications; it introduced an annual report on GCRL activities for fiscal year 1975–76, written by the Director. Seven hundred twenty-five copies of the journal were mailed.

Marine Briefs, the GCRL monthly newsletter continued to be published for the sixth year and mail distribution ranged from 3300 to 3500 copies.

Three new Marine Educational Leaflets were printed. Leaflet No. 7, "Seagrasses and Marine Algae of Mississippi Sound;" Leaflet No. 8, "The Biology (Life Cycle) of Penaeid Shrimp in Mississippi Sound," and Leaflet No. 9, "The Offshore Barrier Islands of Mississippi and Alabama." Leaflets are distributed primarily through the MEC, the PIO/Publications Section, the new Gulf Marine State Park in Biloxi, and the Gulf Islands National Seashore.

A new publication, entitled the Technical Report Series, was introduced in the spring. The first issue, published in May, was entitled "The Menhaden Fishery of the Gulf of Mexico/United States: A Regional Fishery Management Plan." By the end of June, the Section had begun working on the second issue of the Technical Report Series, this one entitled "The Shrimp Fishery of the Gulf of Mexico/United States: A Regional Fishery Management Plan."

ACADEMIC PROGRAM

SUMMER SESSION, Dr. David W. Cook, Registrar

The 1976 summer academic session was the largest in the history of the Laboratory with 126 students registering individually for a total of 170 student courses. Fifty-two students registered through Mississippi schools; 59 through out-of-state affiliates and 15 through nonaffiliated out-of-state institutions. Formal courses offered during the 1976 session were:

Marine Chemistry, Drs. Julia S. Lytle and Thomas F. Lytle, staff
Salt Marsh Ecology, Dr. Lionel N. Eleuterius, staff
Physical Marine Geology, Dr. Ervin G. Otvos, staff
Chemical Marine Geology, Drs. Ervin G. Otvos, Julia S. Lytle and Thomas F. Lytle, staff
Marine Microbiology, Drs. David W. Cook and William W. Walker, staff
Introduction to Marine Zoology, Dr. Buena S. Ballard, Southwestern Oklahoma State University
Marine Vertebrate Zoology and Ichthyology, Dr. J. William Cliburn, University of Southern Mississippi
Marine Invertebrate Zoology, Dr. Edwin W. Cake, Jr., staff
Marine Fisheries Management, Mr. J. Y. Christmas, staff, and visiting specialists
Aquaculture, Dr. Edwin W. Cake, Jr., staff
Parasites of Marine Animals, Dr. Robin M. Overstreet, staff
Marine Ecology, Drs. Robert A. Woodmansee and James T. McBee, staff
Marine Botany, Dr. R. B. Channell, Vanderbilt University
Introduction to Behavior and Neurobiology of Marine Animals, Dr. Leo S. Demski, Louisiana State University Medical School
Special Problems in Marine Science, staff

During the 1976–77 academic year, 69 students earned credit in courses in marine science for teachers that were

offered through the Marine Education Center located in Biloxi. Courses offered were:

Basic Techniques in Marine Science for Teachers, Mr. Gerald C. Corcoran, staff

Advanced Studies in Marine Science for Teachers, Mr. Gerald C. Corcoran, staff

GRADUATE RESEARCH PROGRAM

Courses offered in the graduate research program during this period in which students have participated included: Seminar, Special Problems in Marine Science and Graduate Research in Marine Science.

Three new students were accepted into the Graduate Research Program, one student already in the program withdrew and two completed their research projects and returned to their parent campuses. Eight students in the program were candidates for the master's degree and seven candidates for the doctorate.

Each candidate's name, thesis title, degree sought and home university are listed below according to the research sections directing their work:

Botany Section: Stephen H. Sky-Peck, "The inorganic nitrogenous nutrient requirements of *Juncus roemerianus* and *Spartina alterniflora* in the Gulf of Mexico," M.S., University of Mississippi.

Ecology Section: Jerry A. McLelland, "The summer vertical distribution of Chaetognatha in the northeastern Gulf of Mexico," M.S., University of Southern Mississippi.

John P. Steen, Jr., "Factors influencing the spacial and temporal distribution of selected crustacean plankton species in Davis Bayou," Ph.D., University of Mississippi.

Oyster Biology Section: David H. Barnes, "Seasonal succession and community changes of the polychaete population on an artificial reef," M.S., University of Southern Mississippi.

David A. Blei, "A successional study of the hydrozoans inhabiting an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Neil Cave, "Predator-prey relationships involving the American oyster *Crassostrea virginica* Gmelin, and the black drum *Pogonias cromis* Linnaeus, in the Mississippi Sound," M.S., Southern Louisiana University.

Alfred P. Chestnut, "Substrate competition between *Crassostrea virginica* Gmelin and associated sessile marine invertebrates," Ph.D., University of Southern Mississippi.

John D. DeMond, "Amphipod fouling of an artificial reef in the north central Gulf of Mexico," M.S., University of Southern Mississippi.

Katherine A. McGraw, "A comparison of the growth and survival rates of hatchery-reared and natural oyster spat at selected locations in Mississippi Sound and adjacent waters," Ph.D., University of Washington.

Parasitology Section: Daniel R. Brooks, "Systematic studies on the digenetic trematodes of crocodilians with emphasis on the family Acanthostomidae," Ph.D., University of Mississippi.

Thomas L. Deardorff, "Nematodes of the genus *Thynnascaris* Dollfus, 1933, (Aniskaidae) in the northern Gulf of Mexico," Ph.D., University of Mississippi.

Alan C. Fusco, "The life cycle and development of *Sirocamallanus* sp.," M. S., University of Southern Mississippi.

Tom E. Mattis, "Larval development of two trypanorhynch cestodes from Mississippi Sound," Ph.D., University of Southern Mississippi.

Mobashir Ahmad Solangi, "Pathological changes in some estuarine fishes when challenged by crude oil fractions," Ph.D., University of Southern Mississippi.

Physiology Section: Zubir bin Din, "The food and feeding habits of the common bay anchovy, *Anchoa mitchilli diaphara* Hildebrand," M.S., University of Mississippi.

SPECIAL AND COMMUNITY SERVICES

FISHERY ASSISTANCE

Technical assistance has been provided in response to numerous requests from local fishery industries and to the Mississippi Marine Conservation Commission. Up-to-date information has been maintained on fishery and processing problems, regulations and pending legislation.

Assistance was provided the newly formed Mississippi Shellfish Packers, Inc., a processors' organization, with regard to their presentation to the Mississippi Marine Conservation Commission in opposition to an ordinance banning the taking of crabs with eggs. This led to mutually acceptable modifications in the ordinance.

A conference in blue crab technology was organized with the cooperation of the Sea Grant Advisory Service and held at the Laboratory. A crab meat picking machine was demonstrated at the conference. Subsequently, two Mississippi crab meat processors purchased and installed machines in their plants.

Fishery assistance personnel conducted pre-season shrimp sampling for the MMCC. These data were used by the Commission to help determine the opening date of the shrimp season.

Various and sundry information and advisory assistance were provided on a number of industry problems throughout the year.

SEAFOOD SANITATION

The Microbiology Section has provided bacteriological product testing to local crab processors. These services, conducted at the request of plant owners, are in addition to the

routine samples taken by the Shellfish Sanitation Division of the Mississippi State Board of Health. GCRL services entail a bacteriological survey of the crab from the cook until final packing of the meat. This technical surveillance enables the crab processor to keep a close check on the product he produces, thus ensuring the customer a high-quality product. The same type of assistance is provided to local oyster packers.

In the five months that this bacteriological assistance was offered, GCRL personnel collected and tested over 280 samples (400 manhours) and traveled approximately 375 miles. Each sample was checked for total aerobic counts at 35°C and 20°C, total coliform and total fecal coliform as outlined according to FDA standards.

An educational program entitled "In-Plant Sanitation–Crab Packing Plants" was developed to assist the local crab industry in the education and training of plant personnel. The program is designed to train new personnel in methods of proper sanitation and provide a refresher course for established workers. The slide program is presented by a trained microbiologist. Samples of participants' hair, nails, and smears of hands are cultured on bacteriological media and shown in a follow-up program. It is anticipated that the program will be implemented in all crab-packing plants and be presented at least twice a year. There are plans to make a program on sanitation available in the near future to other area seafood processing plants.

ENVIRONMENTAL AFFAIRS COMMITTEE

This Committee is composed of all senior GCRL scientific staff members and is coordinated by the Ecology Section. It provides an interdisciplinary consideration of environmental problems in the wetlands and estuaries of Mississippi, primarily as a service to the Mississippi Marine Resources Council, which partially funds this work. However, the Committee also cooperates with other State and Federal agencies on special projects not under direct jurisdiction of the MMRC. The majority of these tasks entail reviewing permit requests for work proposed in the wetlands and estuaries. Committee members are asked for comments and recommendations on each permit request. In most cases, a site visit is made by representatives of the Committee. Based upon these inputs, a letter is drafted to the MMRC stating any objections the Committee may have, reasons for these objections and recommendations which may reduce or eliminate the objections.

The Committee reviewed approximately 55 permit applications throughout the year. In addition, an environmental evaluation of an industrial discharge in Mississippi Sound was conducted, and benthic samples were taken and processed for U. S. Fish and Wildlife Service personnel evaluating potential spoil areas for modification of the Pascagoula Ship Channel. Several members of this Committee were involved in meetings with the Mississippi Air and Water Pollution Control Commission in conjunction with the Jackson County 201 Plan.

PUBLIC SEMINARS

The Gulf Coast Research Laboratory hosts a series of staff seminars throughout the year. These seminars are open to the public and speakers include invited scientists as well as officials from various levels of local, state and federal government. The central purpose of the seminars is to promote better dissemination, understanding, and use of scientific information at all levels of society. Seminars presented during fiscal year 1977 were as follows:

"Organization and Continuity of Cell Organelles" by Miss Carolyn Foster, Microscopy Section, Gulf Coast Research Laboratory, July 13, 1976.

"Behavioral Effects of Electrical Stimulation of the Fish Brain" by Dr. Leo S. Demski, Department of Anatomy, LSU Medical School, July 27, 1976.

"The Biology of the Galapagos" by Dr. Martha Nez, Department of Biology, Pensacola Junior College, August 17, 1976.

"Developments in Scientific Data Analysis" by Mr. David Boyes, Computer Section, Gulf Coast Research Laboratory, August 31, 1976.

"Turbidity Plume Studies–Offshore Mobile Bay" by Dr. George Crozier, Assistant Director, Dauphin Island Sea Laboratory, September 14, 1976.

"The Role of the Dauphin Island FDA Laboratory in the National Shellfish Sanitation Program" by Mr. Maynard W. Presnell, Gulf Coast Technical Service Unit, U. S. Food and Drug Administration, October 26, 1976.

"Present Trends in Shrimp Mariculture" by Dr. A. Venkataramiah, Physiology Section, Gulf Coast Research Laboratory, November 16, 1976.

"The Sonoran Desert and Adjacent Life Zones" by Dr. Terry Marsh, Associate Professor of Biology, North Central College, Naperville, Illinois, December 19, 1976.

"Mississippi Sound Circulation" by Mr. Charles K. Eleuterius, Head, Oceanography Section, Gulf Coast Research Laboratory, December 14, 1976.

"Preserving Mississippi's Natural Heritage" by Mr. Joseph W. Jacob, Program Specialist, Mississippi Natural Heritage Program, January 25, 1977.

"Biology of Subterranean Termites" by Dr. Joe K. Mauldin, Principal Entomologist, Southern Forest Experiment Station, February 1, 1977.

"Communicate, Communicate, Communicate" by Miss Catherine Campbell, Public Information Officer, Gulf Coast Research Laboratory, February 22, 1977.

"Bacteria Associated with Blue Crab Meat During Processing and Subsequent Storage" by Ms. Sandra R. Lofton,

Microbiology Section, Gulf Coast Research Laboratory, March 1, 1977.

"Genetic and Chromosome Defects in Clinical Medicine" by Dr. Burwind N. Kaufmann, Chief of Outpatient and Admitting Section, Biloxi Veterans Administration Hospital, March 8, 1977.

"Gametogenesis and Early Development of the American Oyster, Crassostrea virginica" by Mr. Al Chestnut, Oyster Biology Section, Gulf Coast Research Laboratory, April 5, 1977.

"Subduction Along the Western Margin of the Americus Plate" by Mr. Allen Lowrie, Oceanographer, USN, National Space Technology Laboratory, April 12, 1977.

"The Naval Oceanographic Program at NSTL" by Mr. Richard H. Evans, Naval Oceanographic Center, National Space Technology Laboratory, April 19, 1977.

"Computer Applications in the Field of Medicine" by Dr. Danny R. Carter, Chairman, Department of Computer Science, University of Southern Mississippi, May 10, 1977.

STAFF PUBLICATIONS

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